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TECHNICAL REPORT [illegible]

EVALUATION OF PROPOSED DREDGED MATERIAL DISPOSAL ALTERNATIVES FOR NEW YORK/NEW JERSEY HARBOR, PHASE I

by

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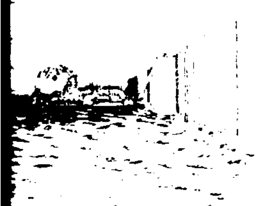

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19 ABSTRACT (Continue on reverse if necessary and identify by block number)

This report documents the field collection of contaminated sediments from the New York/New Jersey Harbor, laboratory testing of those sediments, and initial evaluation of the test results. The work reported in this document is the first phase of a comprehensive evaluation of disposal alternatives for contaminated dredged material from the New York/New Jersey Harbor.

Based upon bioassay/bioaccumulation and base neutral priority pollutant data, field sampling sites were selected by consensus of the Steering Committee. Field sediment samples were collected from the New York/New Jersey Harbor with the assistance and direction of the US Army Engineer District, New York. Material was collected from the most highly contaminated shoals in the harbor. The samples were combined and homogenized to form a worst-case contaminated sediment sample. This sample was then subjected to laboratory testing.

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Laboratory tests performed included analysis for microbial pathogens, sedimentation testing, consolidation testing, and modified elutriate testing. Testing procedures are described, and test results are presented.

Results of the consolidation testing are used to develop containment area filling simulations for each of the confined disposal facilities under consideration. A computerized mathematical model is used to predict the settlement of the dredged material over time. The computer program uses an explicit finite difference technique to solve a finite strain consolidation equation; it makes monthly adjustments to account for any desiccation that has occurred at the dredged material surface.

The microbial pathogens, sedimentation, and modified elutriate test results are used to make preliminary evaluations of effluent water quality from each of the confined disposal facilities (CDF). For more conclusive evaluations to be made, the existing water quality standards at each CDF must be known.

Recommended measures to control the effluent water quality are presented. Because of the preliminary nature of the effluent water quality evaluations, any conclusions concerning site control measures should be considered as interim guidance and should be used only to indicate the direction for future work and investigations.

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SUMMARY

The US Army Engineer District, New York, has requested that the Environmental Laboratory, US Army Engineer Waterways Experiment Station (WES), conduct an evaluation of disposal alternatives for contaminated sediments to be dredged from the New York/New Jersey Harbor. The material that is unacceptable for unrestricted ocean disposal amounts to approximately 5 to 10 percent of the 8 million cubic yards of sediment dredged annually from the New York/New Jersey Harbor area. Of this, an average of 0.38 million cubic yards of dredged material has required capping. The disposal alternatives include: (a) confinement of contaminated material in a 500-acre containment island (with either sand dikes or cofferdam dikes) and (b) confinement of the same material in four smaller, nearshore disposal sites (Bowery Bay, Flushing Bay, Newark Bay, and Raritan Bay). The evaluation is to be conducted in several phases.

The purpose of this Phase I study was to evaluate containment facility effluent quality (including solids retention, contaminant retention, and fate of microbial pathogens) and both the short- and long-term storage capacity of the proposed confined disposal facilities (CDF). A Management Strategy and a Decisionmaking Framework serve as the basis for the testing and decisionmaking described in this study.

Based on bioassay/bioaccumulation and base neutral priority pollutant data, field sampling sites representative of a worst-case scenario were selected by the Steering Committee. Sediment samples from 11 of the most highly contaminated shoals in the Harbor were collected and composited to form the material for laboratory testing. Results of the testing indicated that some restrictions on maximum anticipated dredging flow rates could be required at Flushing Bay, Bowery Bay, and the containment island with sand dikes. Worst-case effluent suspended solids concentrations were predicted and should be compared with appropriate standards when they are identified. The microbial pathogens analysis indicated that some organisms remained in the water column after 96 hr; therefore, chlorination of effluent water may be necessary if the receiving waters do not already contain high levels of these organisms. The estimated effluent contaminant concentrations were of concern for 16 of the 160 parameters analyzed in the modified elutriate test. Appropriately dimensioned mixing zones could provide the required dilution for all of these

parameters except total Kjeldahl nitrogen and ammonia nitrogen, which greatly exceeded the background concentrations. Effluent control measures would be required to reduce the dissolved concentrations of these two parameters to concentrations below background.

The potential service life of each CDF was evaluated considering that (a) no dewatering of the dredged material would occur and (b) dewatering would occur. A maximum service life of 23 years was projected for the containment island with sand dikes when dewatering was considered; the service life of the containment island would be 100 years with no dewatering and 139 years with dewatering if cofferdam dikes were used. When no dewatering of dredged material was considered, the service lives of the four nearshore containment areas varied from a minimum of 9 years at Flushing Bay to a maximum of 52 years at Raritan Bay. With dredged material dewatering, the potential service lives varied from 10 years at Flushing Bay to 69 years at Raritan Bay.

The Phase I studies address the contaminant pathway associated with discharges of contaminants in effluents during active disposal operations. Subsequent studies should address the remaining pathways associated with CDFs. These pathways include surface runoff resulting from precipitation, leaching or seepage into ground water or adjacent surface water, and direct uptake by plants and animals colonizing the site. Additional evaluations of the fate of pathogens are also recommended.

PREFACE

This report was prepared by the Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES), as part of a reimbursable project for the US Army Engineer District, New York. Funding for this investigation was authorized by IAO NYD-85-35 and IAO NYD-86-07.

This report was written by Dr. Marian E. Poindexter, Dr. Douglas Gunnison, Mr. David F. MacIntyre, and Dr. Gary F. Goforth under the general supervision of Dr. Michael R. Palermo, Chief, Water Resources Engineering Group (WREG), EL; Dr. Raymond L. Montgomery, Chief, Environmental Engineering Division (EED), EL; and Dr. John Harrison, Chief, EL. Acknowledgement is made to Ms. Katherine M. Smart, WREG, EED, for assistance in laboratory testing and data reduction. Additional laboratory support was received from Messrs. Roy Wade, Warren Boone, and Sidney Ragsdale of the Water Supply and Waste Treatment Group (WSWTG), EED. Dr. Palermo and Dr. Paul R. Schroeder, WREG, EED, provided input on laboratory testing and evaluations for effluent water quality. Laboratory assistance for the microbial pathogens work was provided by Msses. Cynthia L. Butler, Valerie E. Warner, and Gaye Nell White and Mr. Isaac Smith, Jr., Aquatic Processes and Effects Group, Ecosystem Research and Simulation Division (ERSD), EL. Technical reviewers of the report were Messrs. Norman R. Francinques, Jr., and M. John Cullinane, Jr., WSWTG. The report was edited by Ms. Lee T. Byrne of the Information Technology Laboratory, WES.

COL Dwayne G. Lee, CE, was Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4046.873	square metres
cubic feet	0.02831685	cubic metres
cubic yards	0.7645549	cubic metres
degrees (angle)	0.01745329	radians
Fahrenheit degrees	5/9	Celsius degrees or kelvins*
feet	0.3048	metres
gallons (US liquid)	3.785412	cubic decimetres
g's (standard free fall)	9.806650	metres per second squared
inches	25.4	millimetres
pounds (force) per square foot	47.88026	pascals
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
quarts (US liquid)	0.9463529	cubic decimetres
square inches	6.4516	square centimetres
tons (force) per square foot	95.76052	kilopascals

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

EVALUATION OF PROPOSED DREDGED MATERIAL DISPOSAL ALTERNATIVES FOR NEW YORK/NEW JERSEY HARBOR, PHASE I

PART I: INTRODUCTION

Background

1. In conformance with the Marine Protection, Research, and Sanctuaries Act, both chemical and biological testings of sediments from the New York/New Jersey Harbor have been performed. Test results indicated that approximately 680,000 cu yd,* representing 5 to 10 percent of the total material dredged annually, are unacceptable for unrestricted ocean disposal. This material requires some type of containment or confinement.

2. Harbor and navigation channel sediment contamination is the result of nonpoint sources, combined sewer and storm drain outfalls, agricultural sources, industrial point sources, and spills or illegal discharges. Consequently, these sediments generally reflect a broad range of contamination. The sediments do not meet the Federal statutory requirements for ocean disposal because of toxicity, bioavailability of contaminants, and/or contaminant leaching potential. Contaminants found in these sediments include substances ranging from those prohibited under certain conditions from ocean disposal (cadmium (Cd), mercury (Hg), organohalogens, and petroleum hydrocarbons) to high concentrations of nutrients, metals, and pathogenic microorganisms.

3. For navigation in the New York/New Jersey Harbor to be maintained, the contaminated sediments must be dredged. Disposal of these sediments must be conducted in an environmentally acceptable manner, meeting all Federal, State, and local restrictions. A number of investigations have been conducted to identify and evaluate potential disposal alternatives for these sediments. Two of these alternatives were selected for further detailed assessment in this study: (a) construction of a containment island in a relatively shallow estuarine location that has low biological productivity and (b) construction of containment facilities adjacent to land at various locations in and around

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* A table of factors for converting non-SI units of measurement to SI (metric) is presented on page 9.

the New York/New Jersey Harbor area (Bowery Bay, Flushing Bay, Newark Bay, and Raritan Bay). Locations of the proposed sites are shown in Figure 1. The US Army Engineer Waterways Experiment Station (WES) was requested by the US Army Engineer District (USAED), New York, to evaluate the proposed sites from an environmental and engineering standpoint. This report describes the initial phase of that evaluation.

Purpose and Scope

4. The purpose of this investigation was to evaluate effluent quality, fate of microbial pathogens, and retention of solids during dredging operations, as well as to evaluate the short- and long-term storage capacity of proposed confined disposal facilities (CDFs) for the New York/New Jersey Harbor. The evaluations were based on existing data and limited laboratory testing. The initial testing and evaluation performed for this study provide a basis for identifying additional testing requirements needed for a more complete assessment of the effects of contaminated dredged material disposal. The additional testing requirements will be dependent on the nature of the contaminants and their potential for movement from the sites. This report summarizes the Phase I testing and evaluations; it is not intended to provide detailed operational guidelines for the various disposal options.

5. This study involved the collection of field samples, laboratory testing, and evaluation of results. Representative samples of sediment to be dredged were collected from various locations within the New York/New Jersey Harbor area. The sediments were then transported to the WES and subjected to physical and chemical analyses, settling and modified elutriate tests for prediction of effluent quality, consolidation tests for storage capacity evaluation, and microbial pathogens evaluation. Results of the various tests were evaluated with regard to potential contaminant mobilization in the effluent water. By means of a numerical model, evaluations of the projected filling sequences were made for both the containment island and for the nearshore disposal sites. Effluent water quality predictions were made, and possible site control measures for waste material were identified. Recommendations for further testing and evaluations are included in this report.

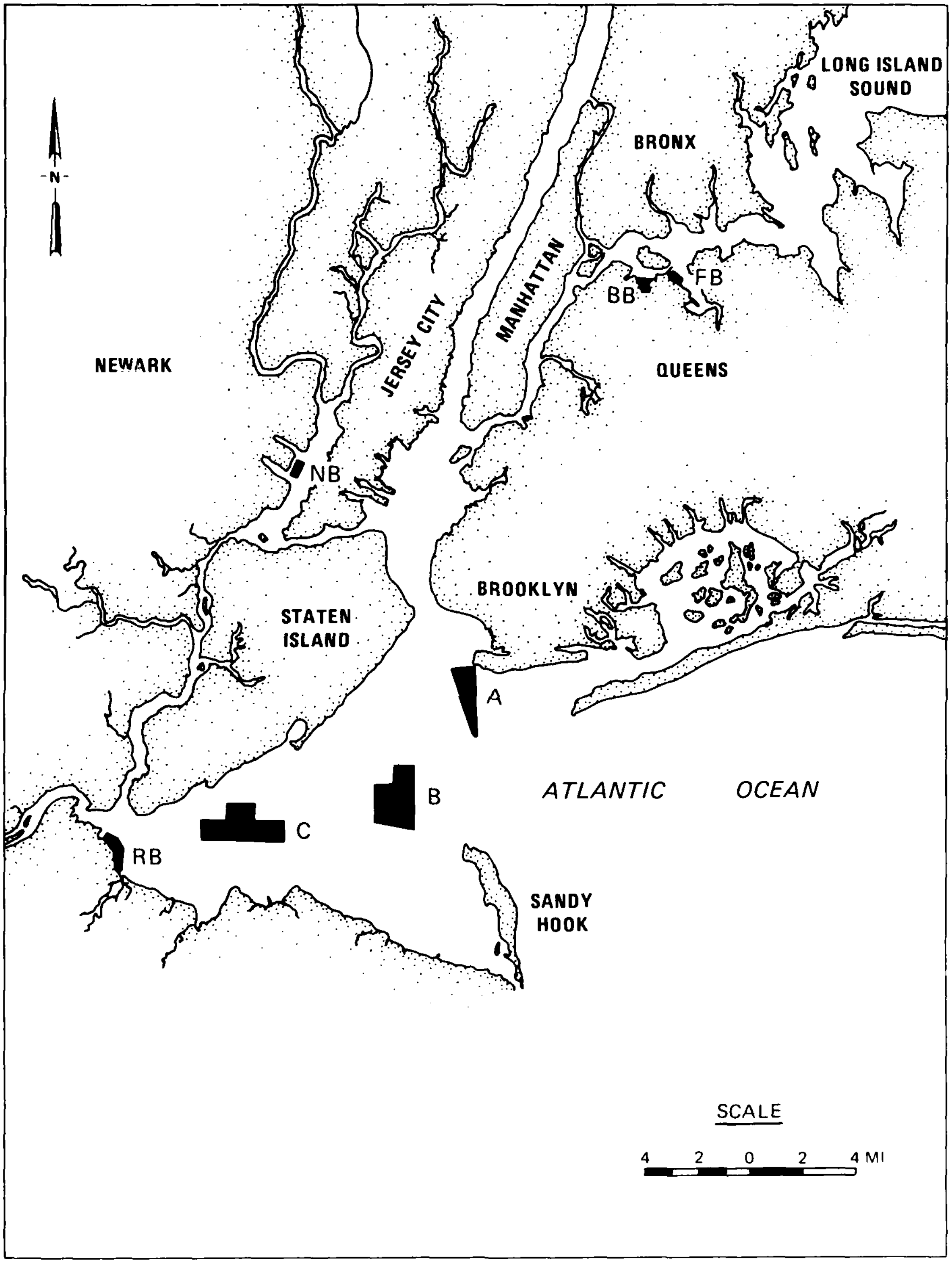


Figure 1. Location of proposed containment island and containment area sites in the New York/New Jersey Harbor

Environmental Considerations for CDF Design

6. CDFs are used to retain dredged material solids while in most cases allowing the carrier water to be released from the disposal area. The two objectives inherent in the basic design and operation of a CDF are: (a) to provide adequate storage capacity to meet long-term dredging requirements and (b) to attain the highest possible efficiency in retaining solids and associated contaminants during the dredging operation. These considerations are interrelated and depend upon effective design, operation, and management of the disposal facility.

7. When contaminated dredged material is placed in CDFs, appropriate considerations must be made to restrict the potential movement of contaminants from the disposal site. Several possible mechanisms by which the contaminants may be transported from confined disposal sites are:

a. Discharge in the effluent during disposal operations.

b. Surface runoff resulting from precipitation following disposal.

c. Leaching into ground water.

d. Direct uptake by plants and animals colonizing the site.

e. Windblown particulates and volatile emissions.

8. Because of funding and scheduling constraints, a comprehensive evaluation of all pathways will be performed in phases. Phase I investigations described in this report addressed only the contaminant pathway associated with effluent quality and related engineering evaluations concerned with retention of solids and storage capacity. The recommended investigations described in Part VIII address the remaining contaminant pathways.

Strategy for Evaluation of Alternatives

General

9. The WES has developed a Management Strategy for disposal of dredged material (Francingues et al. 1985) that describes a logical sequence for testing and evaluation of alternatives for disposal. A Decisionmaking Framework (Lee et al. 1985) has also been developed to provide a methodology for application of the Management Strategy. The Decisionmaking Framework provides a basis for comparison of test results with standards or reference information to determine if contaminant control measures are required in a given instance.

These two documents serve as a basis for the testing and decisionmaking described in this report.

Disposal environments

10. When the proposed containment facilities are filled with contaminated dredged material, the physicochemical conditions controlling contaminant mobility will be a combination of those existing for open-water and upland disposal. Three physicochemical environments will be developed after the filling operation and can be described as:

a. Upland--dry, unsaturated layer.

b. Intermediate--partially saturated layer.

c. Flooded--totally saturated layer.

11. Initially, all of the dredged material will be saturated and anaerobic when placed in the CDF. After the filling operation is completed, the upper surface layer of dredged material between the high-tide and low-tide elevations will become an intermediate layer with a moisture content varying between saturated and unsaturated. The degree of moisture will depend on the rate of water movement through this layer. The layer of dredged material at and below the low-tide elevation will remain saturated.

12. Potential pathways of contaminant migration are illustrated in Figure 2. The three physicochemical environments that may develop at the proposed disposal facility are also indicated.

13. The test protocols specified by the Management Strategy for predicting contaminant mobility at the disposal facilities address the pathways illustrated in Figure 2 and consider the applicable disposal environments. Specific protocols and their associated pathways of contaminant mobility are listed in Table 1.

14. Since filling of the containment facilities will take several years, the characteristics of the materials to be placed in them will likely change. Therefore, the laboratory testing proposed for the initial evaluation of the disposal facilities will be only that necessary to determine site design and control measures required during the initial operation phase.

Criteria for selection of controls

15. No specific standards were available for comparison with test results in determining the need for contaminant controls. Therefore, reference water and marine water quality criteria were selected for interpretation of the test results for effluent quality. Modified elutriate test results

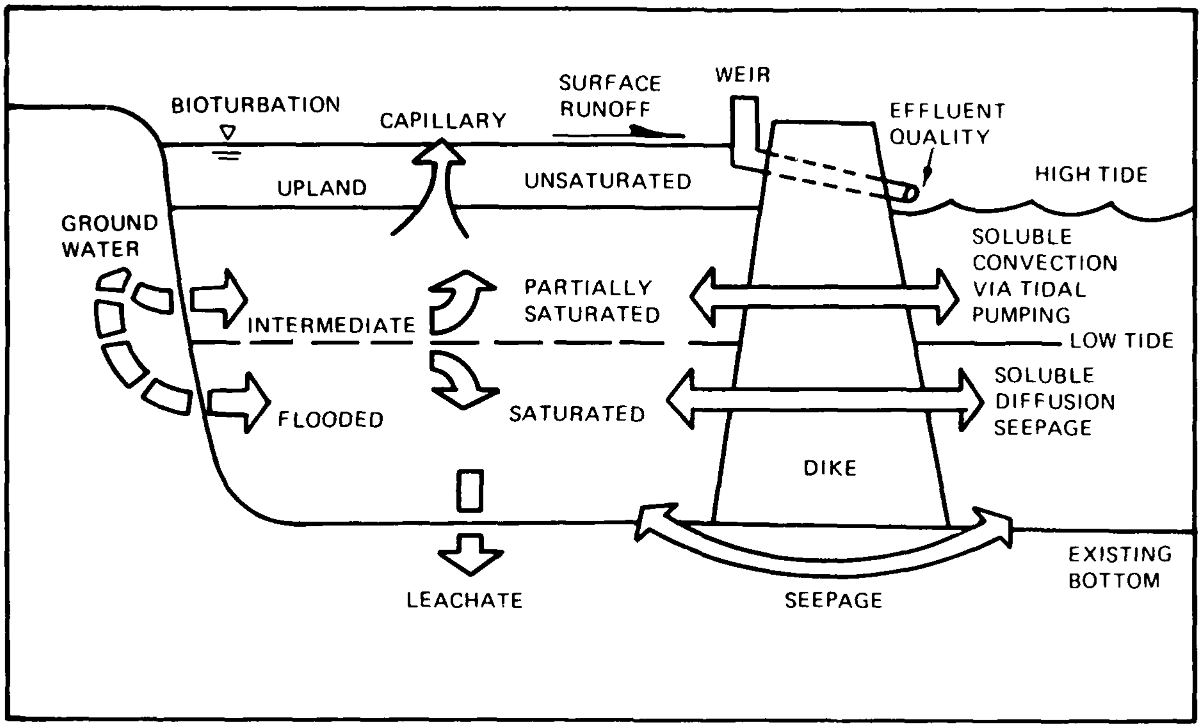


Figure 2. Conceptual framework of a CDF

Table 1

Tabulation of Test Protocol and Pathways of Contaminant Mobility

Test Protocol	Pathway of Contaminant Mobility
Modified elutriate test	Effluent discharge
Surface runoff test	Runoff
Leachate test	Leachate Seepage Soluble diffusion, seepage Soluble convection via tidal pumping Capillary Mobility between layers
Plant bioassay	Direct toxicity and bioaccumulation
Animal bioassay	Direct and indirect toxicity and bioaccumulation

were evaluated in terms of whether they exceeded the reference water concentrations; if so, comparison of test results was made with Federal water quality criteria for the protection of saltwater aquatic life. The reference water was specified as Raritan Bay water and was considered equal to those concentrations determined for the water sample collected for purposes of conducting the modified elutriate tests. For evaluation of microbial pathogens, comparisons were made with existing standards.

PART II: DESCRIPTION OF DISPOSAL ALTERNATIVES

16. Because some of the sediments to be dredged from the New York/New Jersey Harbor are highly contaminated and are therefore not acceptable for unrestricted ocean disposal, they must be placed in some type of confined or contained facility. Two alternative disposal options are being considered: confinement in one 500-acre containment island or confinement in four smaller disposal sites to be constructed nearshore in the Harbor area.

Containment Island

17. The containment island concept involves construction of a 500-acre island in the New York/New Jersey Harbor. This island should be located in a relatively shallow area to minimize construction problems and costs. The area should have good native foundation soils that can provide a firm foundation on which to construct the confining dikes. By locating the disposal island at such a site, the quantity of dike construction materials required will be minimized since less displacement of foundation material will occur and dike side slopes can be steeper. Additionally, the containment island should be located in an area of low biological productivity to minimize any negative impacts on the environment. Several potential containment island locations have been identified by the USAED, New York, and are presently being evaluated. Since no particular site has been selected for the containment island, the filling simulation for the island will be generic.

18. Because recommended designs for retaining dikes at the containment island have not been developed, two dike configurations were used for the analyses in this study. The first configuration involved the use of cofferdam-type confining dikes as shown in Figure 3. This dike configuration resulted in an area for dredged material storage of 500 acres. The second configuration, shown in Figure 4, used sand dikes with an average side slope of 1:30 below the waterline and 1:8 above the water surface. The use of sand dikes resulted in a dredged material storage area of approximately 117 acres. A smaller area was associated with the sand dike configuration because it was assumed that the dikes were completely contained within the 500-acre surface area. For both of these dike configurations, the dikes were assumed to be located in 20 ft of water and to have a maximum height of 45 ft. Therefore,

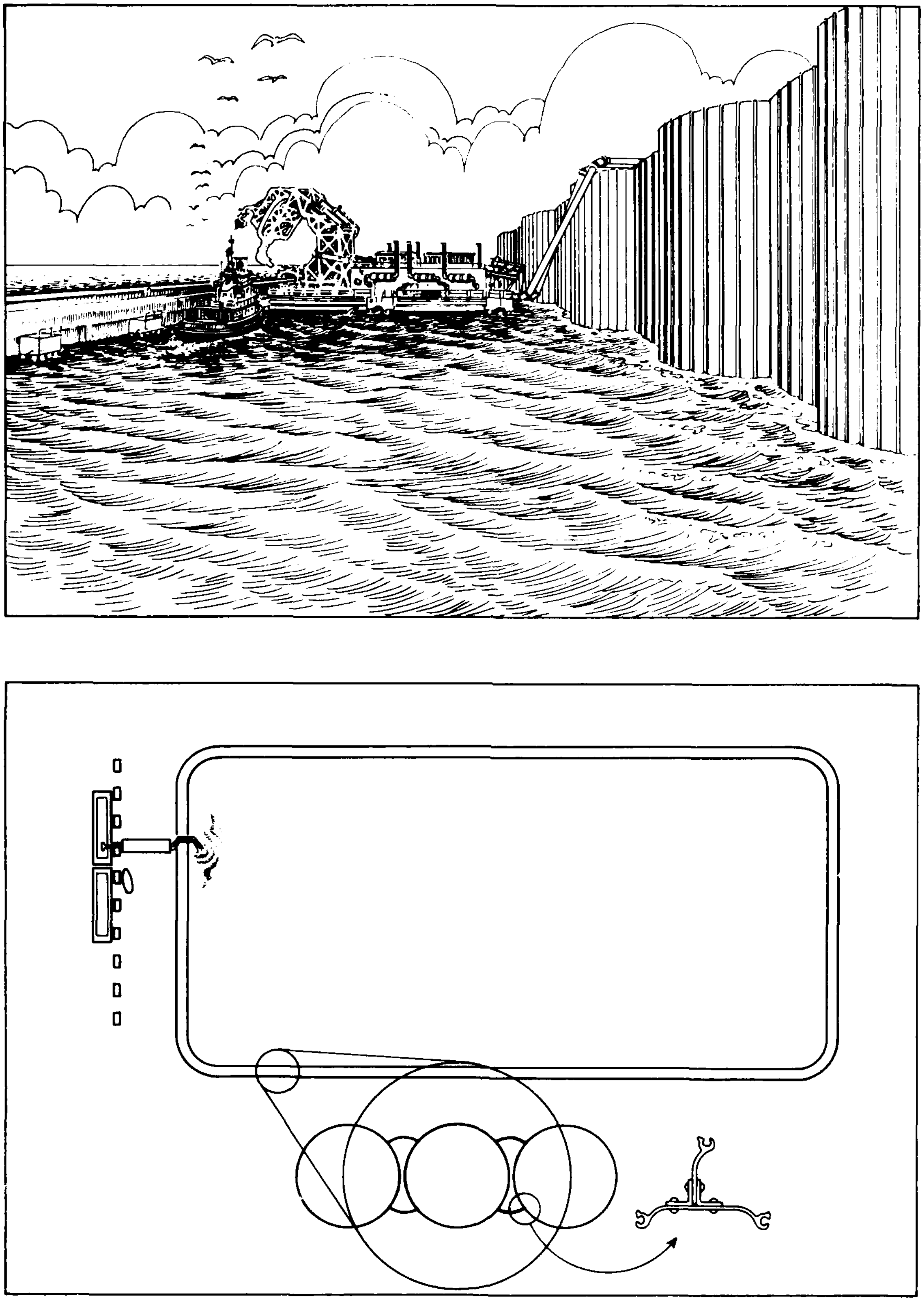


Figure 3. Illustrative drawing of cofferdam dikes for the disposal island

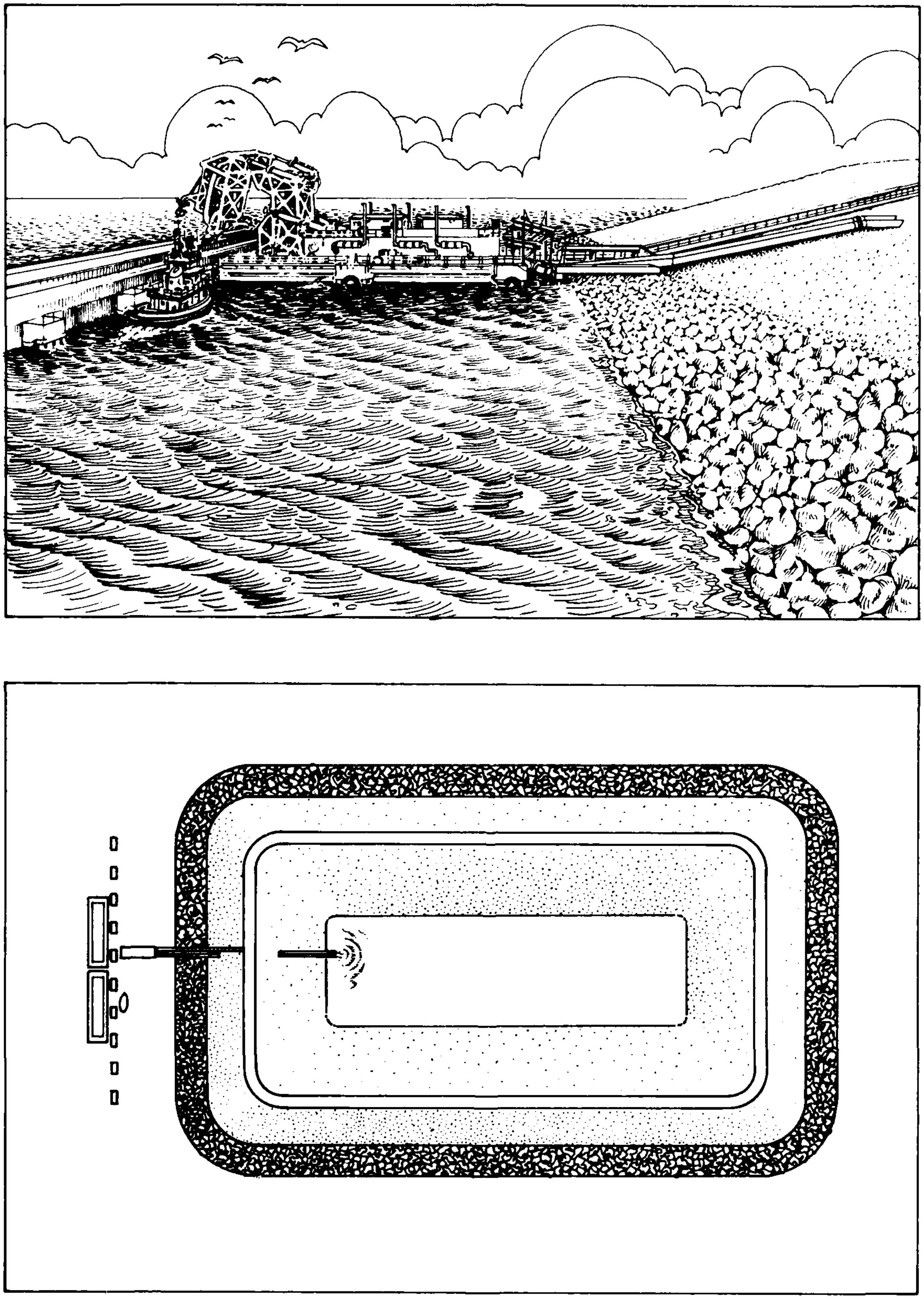


Figure 4. Illustrative drawing of sand dikes for the disposal island

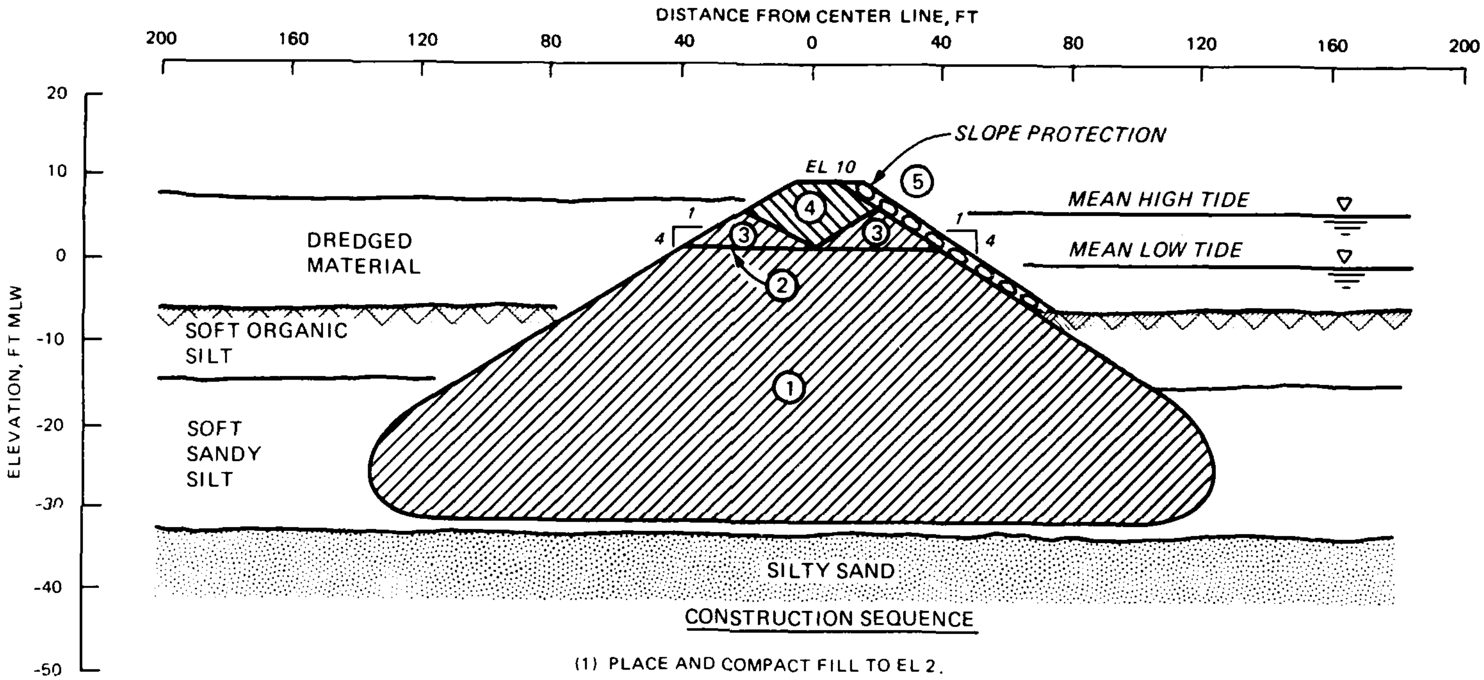
the dike crest elevation for either dike type would be elevation (el) +25 mean low water (MLW). A freeboard requirement of 10 ft was established by Walski (1986) for the containment island. This limited disposal into the sites to surface elevations at or below el +15 MLW.

19. Foundation conditions for the 500-acre containment island were not known since a specific location for such an island had not been identified and therefore site-specific foundation investigations had not been conducted. According to Walski and Schaefer (1988), three sites in Lower New York Harbor have been under consideration for the containment island; these sites are identified in Figure 1 as Sites A, B, and C. The limited information available in Bokuniewicz and Fray (1979) indicates that Site B is located on a sandy foundation soil that is not expected to undergo consolidation as a result of island construction. Site C may be located over a thin clay layer that is underlain by extensive incompressible sand deposits. No information on the foundation conditions at Site A was available. For purposes of this analysis, the foundation soil for the containment island was assumed to be incompressible. This assumption was consistent with the majority of the available data; it was also a conservative assumption since consolidation of foundation soils typically results in increased storage capacity of a CDF.

Containment Areas

20. The second disposal alternative is to construct four containment areas adjacent to land in various areas in and around the New York/New Jersey Harbor. Four sites have been identified by the USAED, New York, for this use: Bowery Bay, Flushing Bay, Newark Bay, and Raritan Bay. Foundation conditions at these sites had been investigated as a part of a previous study, and recommended dike designs had been developed (Poindexter, in preparation). For purposes of this study, the dike configurations developed in the previous study have been used to allow the analysis to be site specific as well as to allow a direct comparison of the results of this analysis with previous results.

21. The retaining dikes at each of the four smaller sites were assumed to have the configurations reported in Poindexter (1986) and are shown in Figures 5 through 8. The dike crest elevations for Bowery Bay, Flushing Bay, and Raritan Bay were taken to be el +10 MLW, whereas the dike crest elevation for Newark Bay was el +12 MLW. This difference in elevations resulted from an



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(3) PLACE OUTSIDE SECTION TO ANCHOR AND STRETCH FILTER CLOTH.
(4) CONSTRUCT CENTER SECTION.
(5) PLACE FILTER CLOTH AND ROCK PROTECTION.

Figure 5. Dike cross section for Bowery Bay, New York

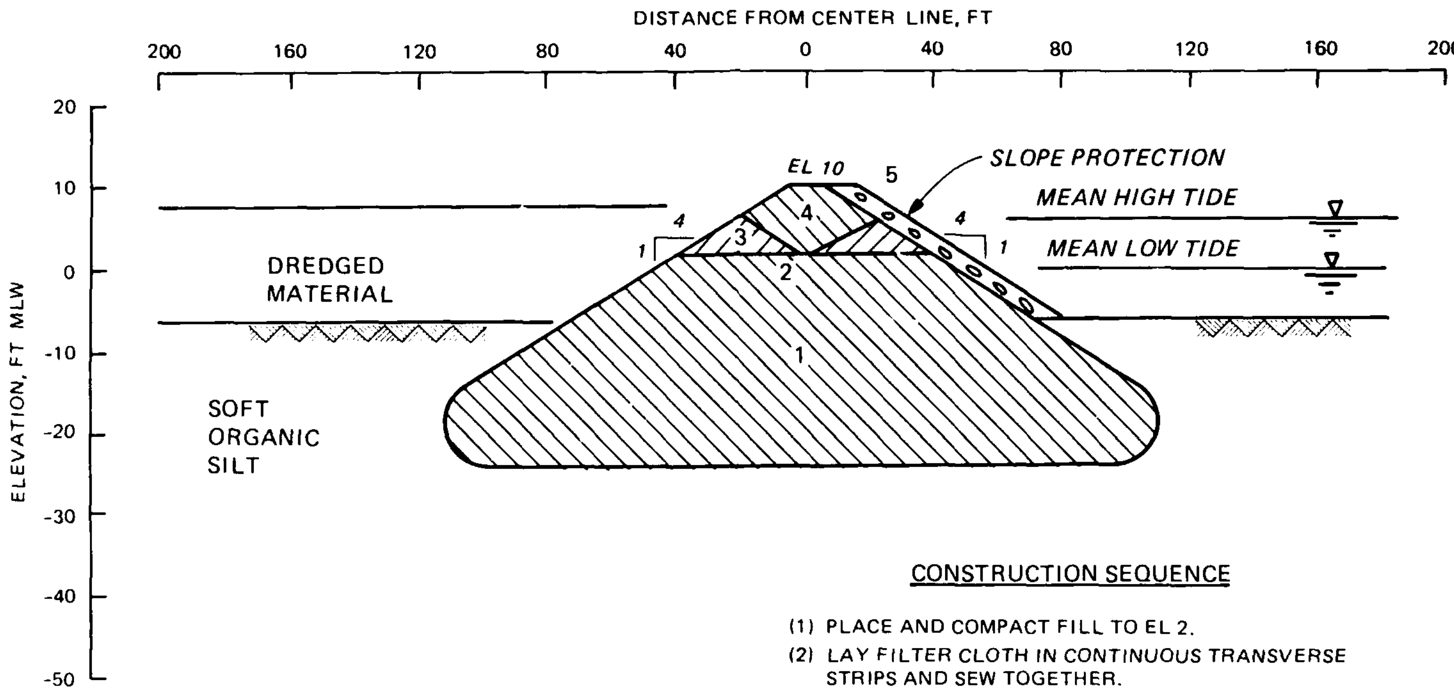

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Figure 6. Dike cross section for Flushing Bay, New York

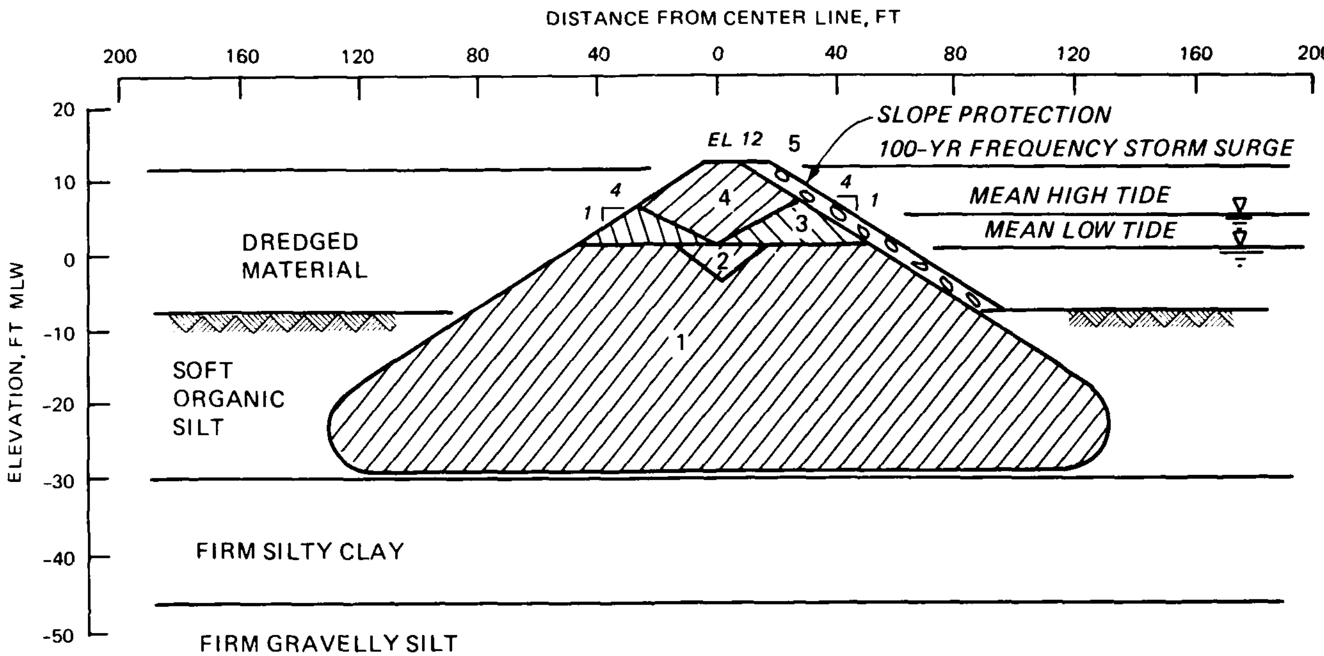

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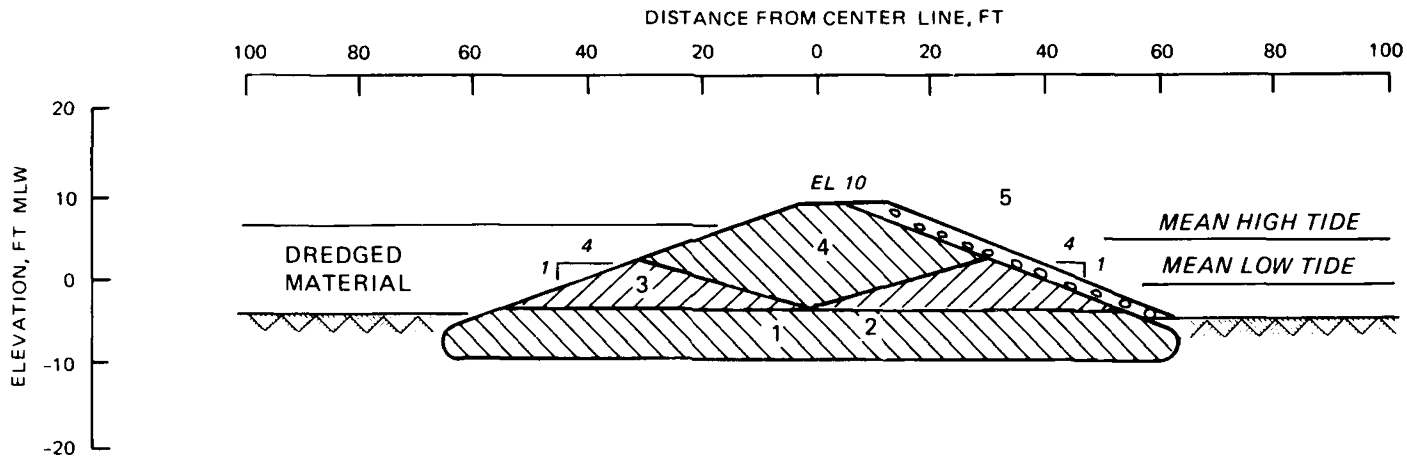
Figure 7. Dike cross section for Newark Bay, New York



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(5) PLACE FILTER CLOTH AND ROCK PROTECTION.

Figure 8. Dike cross section for Raritan Bay, New Jersey

initial assumption in the previous study that a dike crest elevation of el +10 MLW would be adequate for the tides and expected storm surges in the New York/New Jersey Harbor. After completion of three of the four dike designs, the decision was made by the sponsor to change the maximum dike crest elevation to el +12 MLW for the remaining site, which was Newark Bay. A 2-ft freeboard requirement was established for each of the four upland sites.

22. Each of the four smaller sites evaluated in this study is underlain by a thick compressible soil stratum as shown in Figures 9 through 12. Because no consolidation data were available for the foundation soils at any of the four sites, the most representative compressibility data available were used. The void ratio-effective stress and the void ratio-permeability relationships for the assumed representative foundation soil are given in Table 2.

General Site Conditions

23. In the following paragraphs, the general conditions that may affect the analysis and/or performance of the sites are discussed. These site conditions must be considered for evaluation of microbial pathogens, effluent water quality, and disposal site capacity. In cases where no site-specific data were available, assumptions were made based upon the limited related data and previous experience with other similar sites and materials.

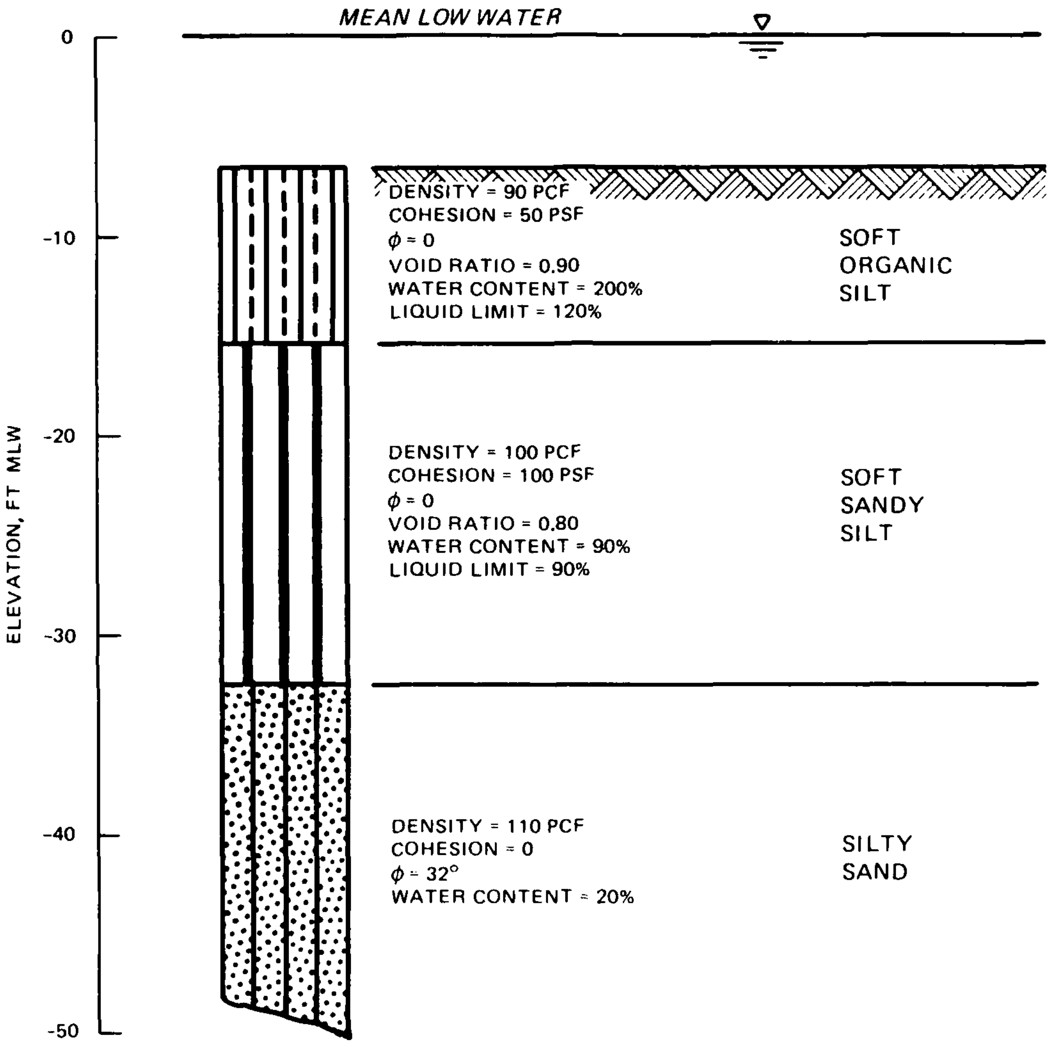
Tides

24. The average tidal fluctuation in the New York/New Jersey Harbor area is approximately 5 ft. For purposes of this study, datum was taken as mean low water (el 0 MLW), and mean high water was taken as el +5 MLW. This information was obtained from the National Oceanic and Atmospheric Administration (NOAA) tide tables (1984).

Climatological data

25. Use of climatological data is necessary whenever dredged material may be subjected to evaporative drying. The data are needed in this analysis since a portion of the storage volume at each of the disposal sites is located above mean high tide and thus some of the dredged material may be subjected to evaporative drying.

26. The monthly averages for rainfall and evaporation in the New York/New Jersey Harbor area were calculated. The rainfall data were obtained from NOAA (1980) and were averaged for a period of 50 years. Evaporation data were



NOTE: SOIL PROFILE AND DESIGN PARAMETERS ARE BASED ON AVAILABLE DATA.
DESIGN PARAMETERS ARE BELIEVED REASONABLE (THEY MAY BE CONSERVATIVE).

Figure 9. Simplified soil profile at Bowery Bay, New York

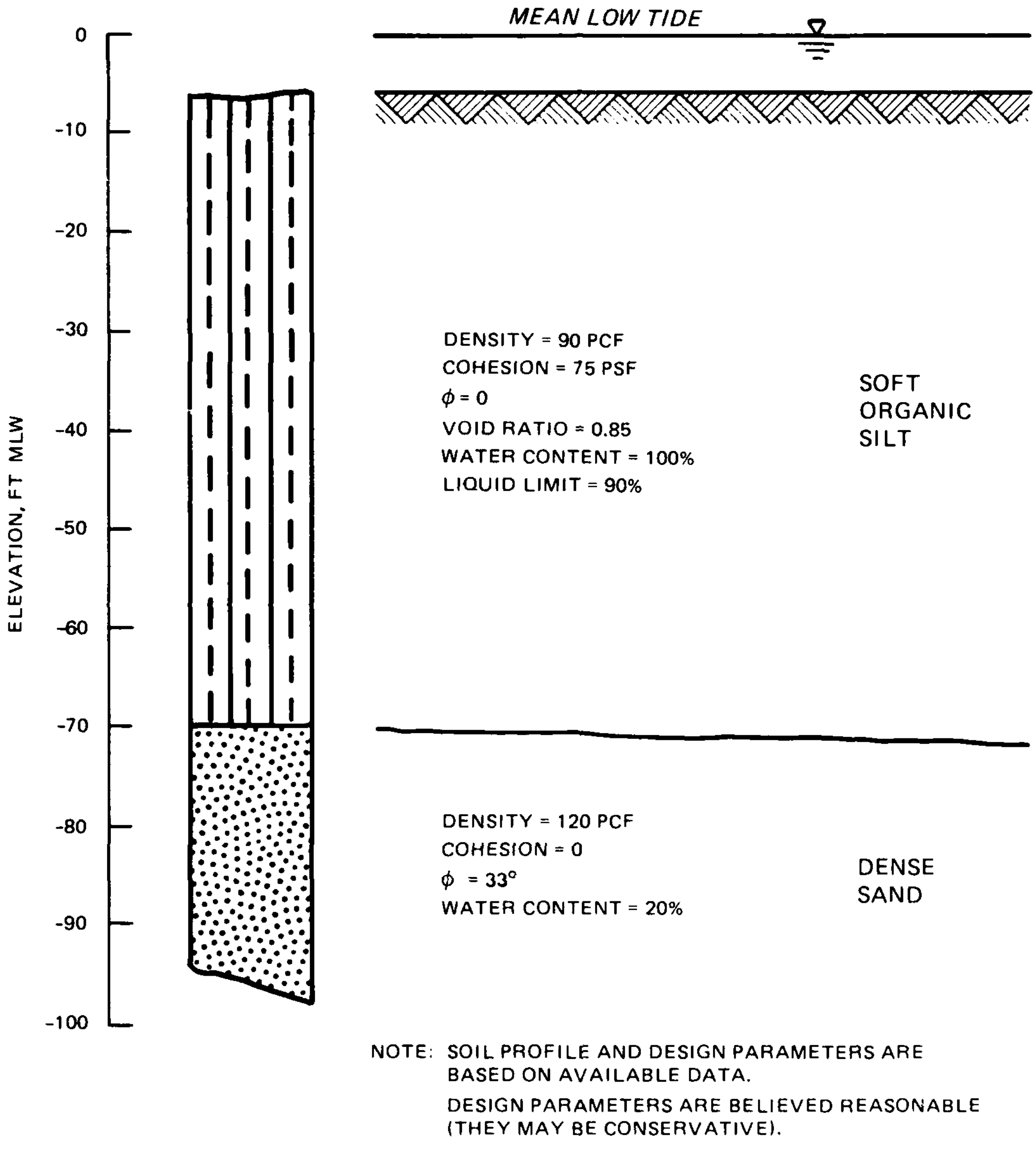
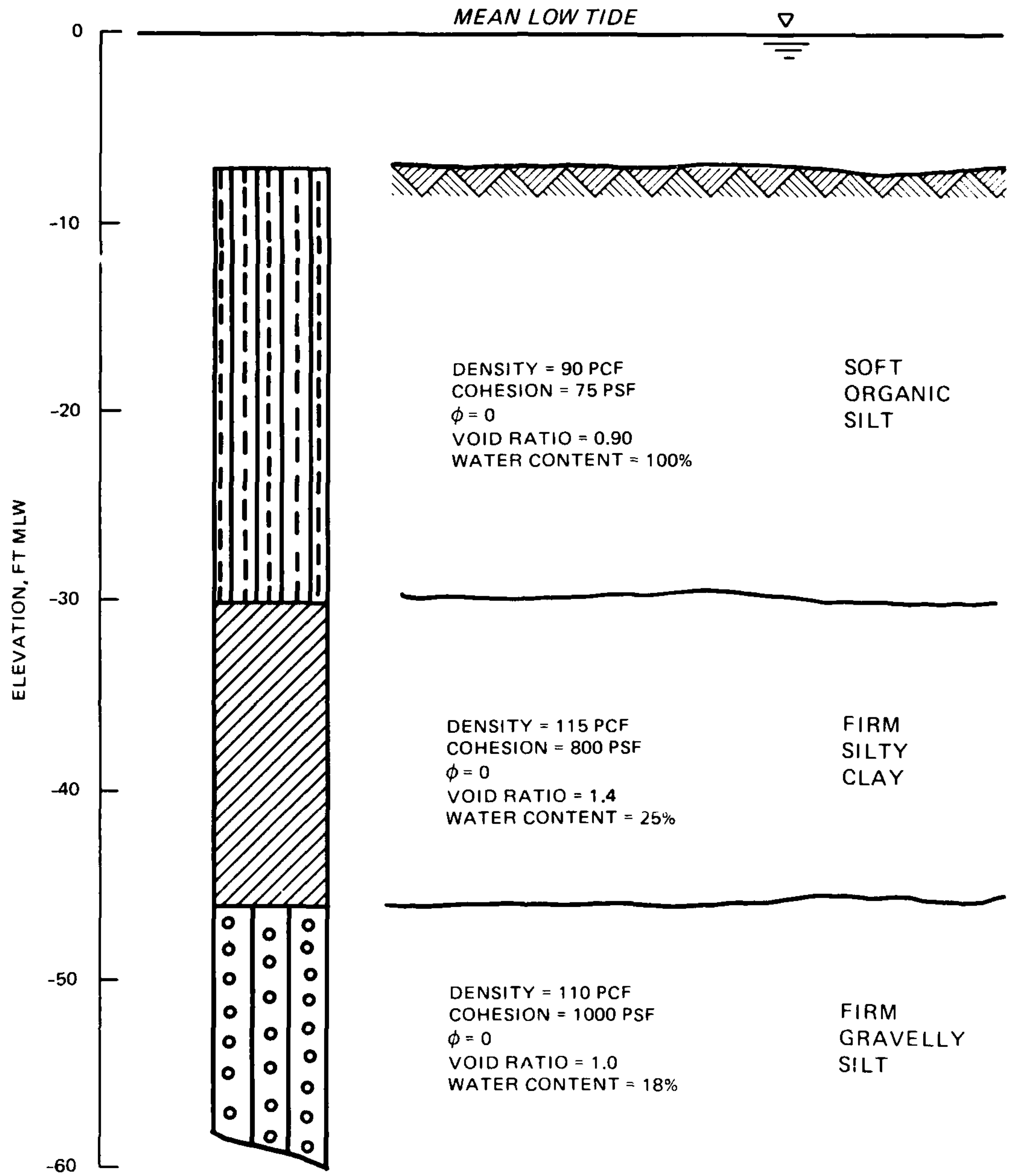


Figure 10. Simplified soil profile at Flushing Bay, New York



NOTE: SOIL PROFILE AND DESIGN PARAMETERS ARE BASED ON AVAILABLE DATA.

DESIGN PARAMETERS ARE BELIEVED REASONABLE (THEY MAY BE CONSERVATIVE).

Figure 11. Simplified soil profile at Newark Bay, New Jersey

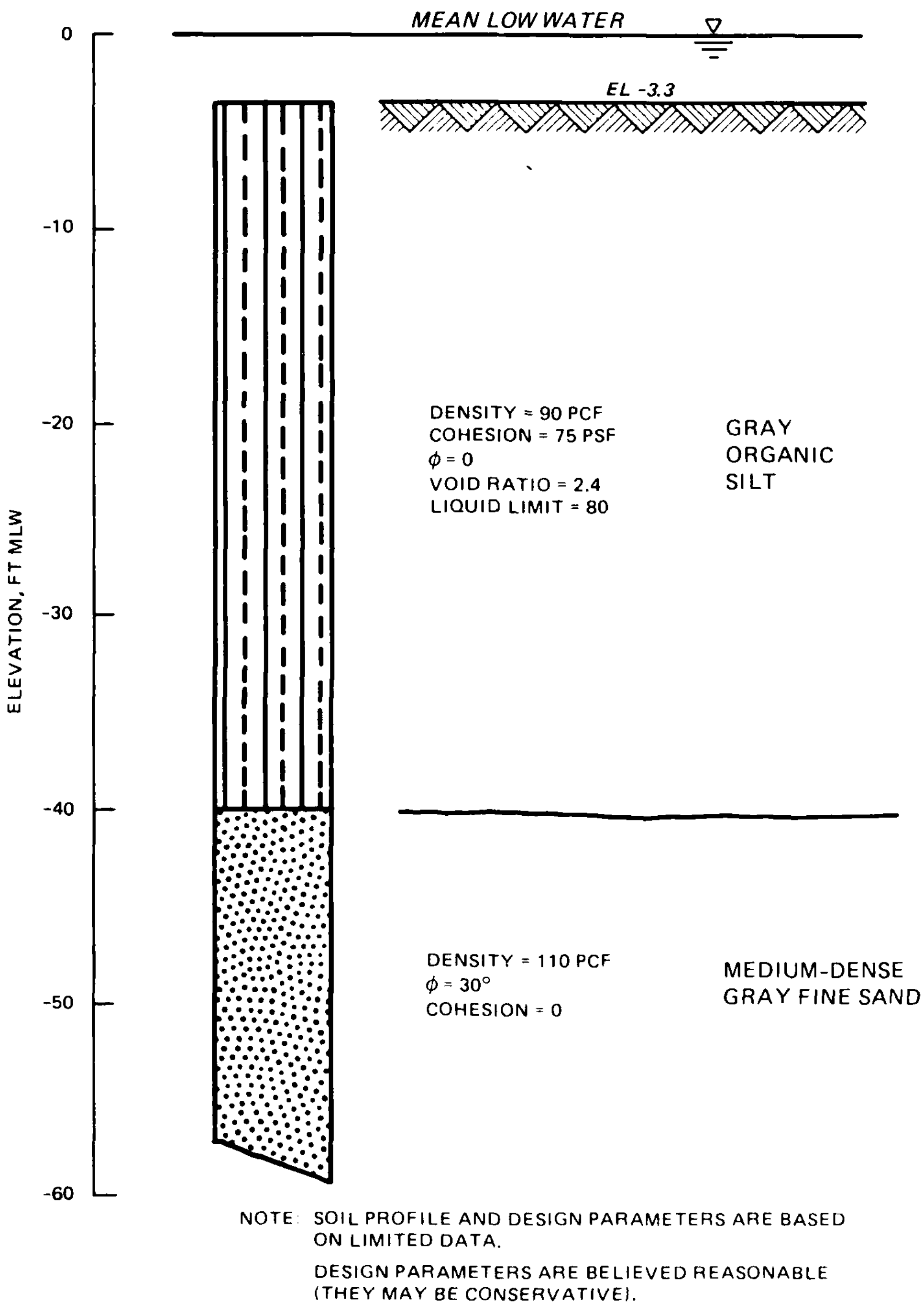


Figure 12. Simplified soil profile at Raritan Bay, New Jersey

Table 2

Assumed Consolidation Characteristics of the Foundation

Soil for Bowery, Flushing, Newark, and Raritan Bays*

Void Ratio	Effective Stress psf	Permeability ft/day
4.00	0.00	5.47E-03
3.90	0.50	5.04E-03
3.85	1.10	4.82E-03
3.80	1.90	4.68E-03
3.70	4.00	4.32E-03
3.60	8.20	3.96E-03
3.50	13.20	3.67E-03
3.40	19.80	3.34E-03
3.30	28.00	3.05E-03
3.20	37.40	2.81E-03
3.10	50.00	2.56E-03
3.00	64.00	2.33E-03
2.90	84.00	2.13E-03
2.80	110.00	1.92E-03
2.70	140.00	1.73E-03
2.60	182.00	1.54E-03
2.50	240.00	1.38E-03
2.40	316.00	1.21E-03
2.30	400.00	1.05E-03
2.20	460.00	9.07E-04
2.10	700.00	7.78E-04
2.00	880.00	6.62E-04
1.90	1,140.00	5.40E-04
1.80	1,480.00	4.42E-04
1.70	1,900.00	3.53E-04
1.60	2,460.00	2.84E-04
1.50	3,200.00	2.23E-04
1.40	4,160.00	1.73E-04
1.30	5,400.00	1.34E-04
1.20	7,000.00	1.02E-04
1.10	9,000.00	7.63E-05
1.00	11,400.00	5.90E-05

* The specific gravity of the foundation soil was assumed to be 2.70.

averaged over a 30-year period (Haliburton 1978). The data used in the analysis are shown in Table 3.

Sediments

27. The sediment to be placed in the CDFs under investigation is the composite sample that was collected in New York/New Jersey Harbor and has been

Table 3

Average Monthly Climatological Data for New York/New Jersey Harbor Area

Month	Rainfall, in.	Pan Evaporation, in.
January	3.31	0.00
February	3.02	0.00
March	3.94	0.00
April	3.58	1.92
May	3.51	4.80
June	3.42	4.92
July	3.77	5.88
August	4.23	3.84
September	3.63	4.68
October	3.07	1.92
November	3.53	0.00
December	3.45	0.00

tested as a part of this study. Consolidation characteristics of the fine-grained portion were determined using the large strain, controlled rate of strain (LSCRS) consolidometer as well as the self-weight consolidation test. The physical properties and compressibility data for this sediment are given in Part V.

28. The quantity of material to be placed in CDFs is approximately 0.68 million cu yd annually. For the containment island scenario, the entire quantity will be placed in the island. For the four-site scenario, the material will be divided equally among the four sites; therefore, each site will receive 169,000 cu yd (bin yardage) annually. The thickness of the dredged material layer deposited at a site will depend upon the quantity of material placed and the surface area of the CDF. For each site, the acreage of the disposal site, the quantity of material (bin yardage), and the resulting lift thickness after hydraulic pumping are listed in Table 4, along with relevant CDF characteristics. It should be noted that the lift thickness is not obtained by dividing the volume of material deposited by the surface area of the site. Several intermediate calculations are required to account for the

Table 4

Physical Characteristics of the CDF

Parameter	Disposal Island Sites: Sand Dike	Disposal Island Sites: Cofferdam Dike	Nearshore Sites: Raritan Bay	Nearshore Sites: Newark Bay	Nearshore Sites: Bowery Bay	Nearshore Sites: Flushing Bay
Ponding area (acres)	117	500	335	156	65.4	53.7
Dike crest (ft, MLW)*	25	25	10	12	10	10
Freeboard (ft)	10	10	2	2	2	2
Thickness of compressible foundation (ft)	0	0	35	30	20	75
Top of incompressible foundation (ft, MLW)	-20	-20	-36	-35	-27	-80
Storage capacity (with freeboard) (MCY)**	28.23	6.61	4.86	3.78	1.58	1.13
Dredging volume (MCY/yr)	0.676	0.676	0.169	0.169	0.169	0.169
Lift thickness (ft)	5.42	1.27	0.47	1.02	2.42	2.95

* MLW = mean low water.
** MCY = million cubic yards.

change in dredged material void ratio between the transport barge and the containment area. During field investigations, the void ratio of the sediment was determined to be 4.84 in the channel. The average void ratio at the end of the dredging period was estimated from the self-weight consolidation test data to be 8.75. The sand content of the sediment was determined to be 11.8 percent; the sand was assumed to settle out of suspension near the CDF inflow pipeline and to attain a void ratio of 2.0.

Disposal operations

29. Because specific dredging schedules were not available at the time of this study, certain assumptions were required. It was assumed that dredged material was deposited into each containment area only once per year. More frequent placement of material would not significantly affect the ultimate amount of consolidation expected to occur in the deposit, but it would affect the rate of consolidation and possibly the amount of desiccation drying. If desiccation does not occur as anticipated in this study, a significant reduction in storage capacity could result if full advantage of the summer drying period is not achieved.

30. A second assumption was made regarding the time of year at which the dredging/disposal operation would begin. It was assumed that all dredging operations would begin in January. This assumption is significant only because the evaporative drying rates vary during different seasons of the year. The most effective drying period in the New York Harbor area is May to September, whereas no significant evaporative drying occurs during the period of November through March. If the dredged material is allowed to dry for a period of 1 year, then the effect of the timing of the initiation of dredging is insignificant.

31. An additional assumption was made regarding the time that would elapse between initiation of disposal operations and the decantation of ponded surface water or beginning of evaporative drying in the disposal site. A period of 90 days (3 months) was assumed for all cases in which evaporative drying would occur. Drying of the dredged material surface was allowed only when the surface was above mean high water (el +5 MLW). This elevation was taken to be the elevation of a permanent water table within the deposited dredged material since it represents a worst case condition, i.e., the case in which the least gain in storage capacity would be realized from evaporative drying. Actual water table conditions could not be predicted since information was not available for site operating procedures, permeability of dikes, permeability of foundation soils, and general hydrologic conditions at the site.

32. For the four-site disposal alternative, the storage life of each of the sites was different because of differences in CDF physical dimensions and dredged material lift thicknesses. During the filling simulations, it was assumed that as the smaller sites were filled, their remaining disposal volume

was deposited in the largest site, the Raritan Bay CDF. Any material remaining after the Raritan Bay CDF was filled was deposited in the Newark Bay facility.

PART III: FIELD INVESTIGATIONS

33. Field collection of sediment samples from the New York/New Jersey Harbor was necessary to determine both the physical and chemical characteristics of the contaminated material to be dredged. Within the harbor, sediment samples were collected from 13 separate locations that were expected to have high levels of contaminants. The sediment sampling locations were chosen to represent a "worst case" mixture of contaminated dredged material. The samples collected for laboratory testing were later combined to create one sediment sample that should be representative of the dredged material as it will exist after hydraulic placement in a CDF.

Sampling Locations

34. Initial identification of potential sediment sampling locations was accomplished by using results from a previous study conducted under contract for the USAED, New York (Malcolm Pirnie, Inc. 1984). This study presented bulk sediment chemistry analyses in which samples from 23 sites in and around the New York/New Jersey Harbor were analyzed for all the priority pollutants as designated by the Environmental Protection Agency (EPA).

35. In order to locate the sites in the study area with the highest levels of contamination, the results from the Malcolm Pirnie study were used to estimate an approximate cumulative toxicity value for each of the individual sites. This estimation was necessary since a number of pollutants of various toxicities were present in varying concentrations at each site and since an overall site toxicity value was needed to identify the most highly contaminated locations.

36. The cumulative toxicity value for each of the 23 sites was estimated as follows. The concentrations of individual contaminants were normalized by dividing the detected concentration for the contaminant by a toxicity rating for that contaminant. The toxicity ratings used were those based on mammalian lowest-published-toxic-dose (TDLo) values because these were the only measures of toxicity that could be found for all the chemicals. TDLo is the lowest dose of a substance introduced by any route, other than inhalation, over any given period of time and reported to produce carcinogenic, neoplastic, or teratogenic effects in animals or humans (Sax et al. 1984). Mammalian

TDLo values are not necessarily an accurate measure of toxicity in an aquatic environment, nor are synergistic toxic effects accounted for by this method. However, even with these limitations, it was felt that this form of analysis would give a better estimate of total toxicity than would using the nonnormalized contaminant concentrations. To get a significantly more accurate measure of the sites' relative toxicities would require an aquatic bioassay of sediment from each site.

37. The normalized contaminant concentrations were summed at each sampling location to arrive at a rough estimation of the station's relative cumulative toxicity. It was found that several stations exhibited high relative toxicities because of a mixture of heavy metal contaminants and several others showed high relative toxicities because of a mixture of polynuclear aromatic hydrocarbons (PAHs). Since most sites did not show a high relative toxicity in both categories, it was decided to select several sites of each type for subsequent sampling.

38. The potential sampling locations were discussed in a meeting on 6 June 1985 among representatives of the USAED, New York; WES; the Steering Committee; and Vice-Chairpersons of the Public Involvement Coordination Group (PICG). The Steering Committee is composed of Federal and state regulatory agencies. The PICG is a public involvement group that comments on the Dredged Material Disposal Management Plan for the Port of New York and New Jersey (of which feasibility studies for containment islands and areas are a part). The Steering Committee and PICG agreed by consensus on the sample locations that would represent the worst-case scenario for the New York/New Jersey Harbor area. The sediment sampling locations that were used are shown in Figure 13. Location descriptions for each of the sediment sampling sites are given in Table 5.

39. The samples taken in Arthur Kill at the Outerbridge Crossing (Site S8) and in the Raritan Bay West Reach (Site S9) were discarded since these sample areas did not show any recent fine-grained sedimentary material. Since significant contaminant concentrations are usually associated with recent fine-grained sediment deposits, these samples were probably not highly contaminated and were therefore discarded. Of the two grab samples taken at the Arthur Kill Outerbridge Crossing, the first yielded a mixture of sand and gravel that contained live clams up to 2-1/2 in. wide, live marine snails, and a polychaete. The second, taken about 1,600 ft from the first, consisted of a

1/8-in. layer of coarse sand and broken shell lying on top of consolidated black clay. The Raritan Bay West Reach sample consisted of very stiff consolidated black clay. Live clams were also found at Elizabeth Channel (Site S4), at Shooters Island (Site S5), and between Piers 98 and 99 (Site S13).

40. Water samples were taken at 11 sites identified in Figure 13 and described in Table 6. These sites were chosen because they are adjacent to proposed containment areas. They should therefore be representative of the water that would be used to reslurry dredged materials after they are barged to the containment areas.

Sample Collection

41. Samples were collected 11 through 17 June 1985 using Corps of Engineer (CE) boats MV *Gelberman* and MV *Hudson*. Sampling site locations were determined in the field using fixed reference points such as navigation buoys or installations onshore. At each sampling site, the location was also noted by recording the loran coordinates of that point.

Sediment sampling

42. Sediment samples were taken using a pneumatically actuated grab sampler. The clamshell bucket of the sampler was capable of collecting approximately 20 gal of sediment with each grab. The bucket was lifted above the surface of the water and suspended there until all the excess water had run out. It was then swung on board the boat, lowered to within 3 in. of the deck, and opened, allowing the sediments to fall to the boat deck. The sediment samples were usually sufficiently undisturbed so that any nonhomogeneity or stratification was clearly visible.

43. At each sediment sampling site, 10 gal of sediment were collected for physical analyses, such as soil classification, sedimentation, and consolidation testing; and a 1-qt sample was taken for chemical analysis. The samples for physical analyses were shovelled into 5-gal plastic buckets with waterproof self-sealing lids. The samples for chemical analysis were picked up with a metal scoop and placed into wide-mouthed glass jars with Teflon-lined screw tops. All sample containers were washed to remove any sediment from the exterior of the jars and were then placed in a cooler. Finally, all remaining sediment was washed off the deck as the boat travelled to the next sampling location.

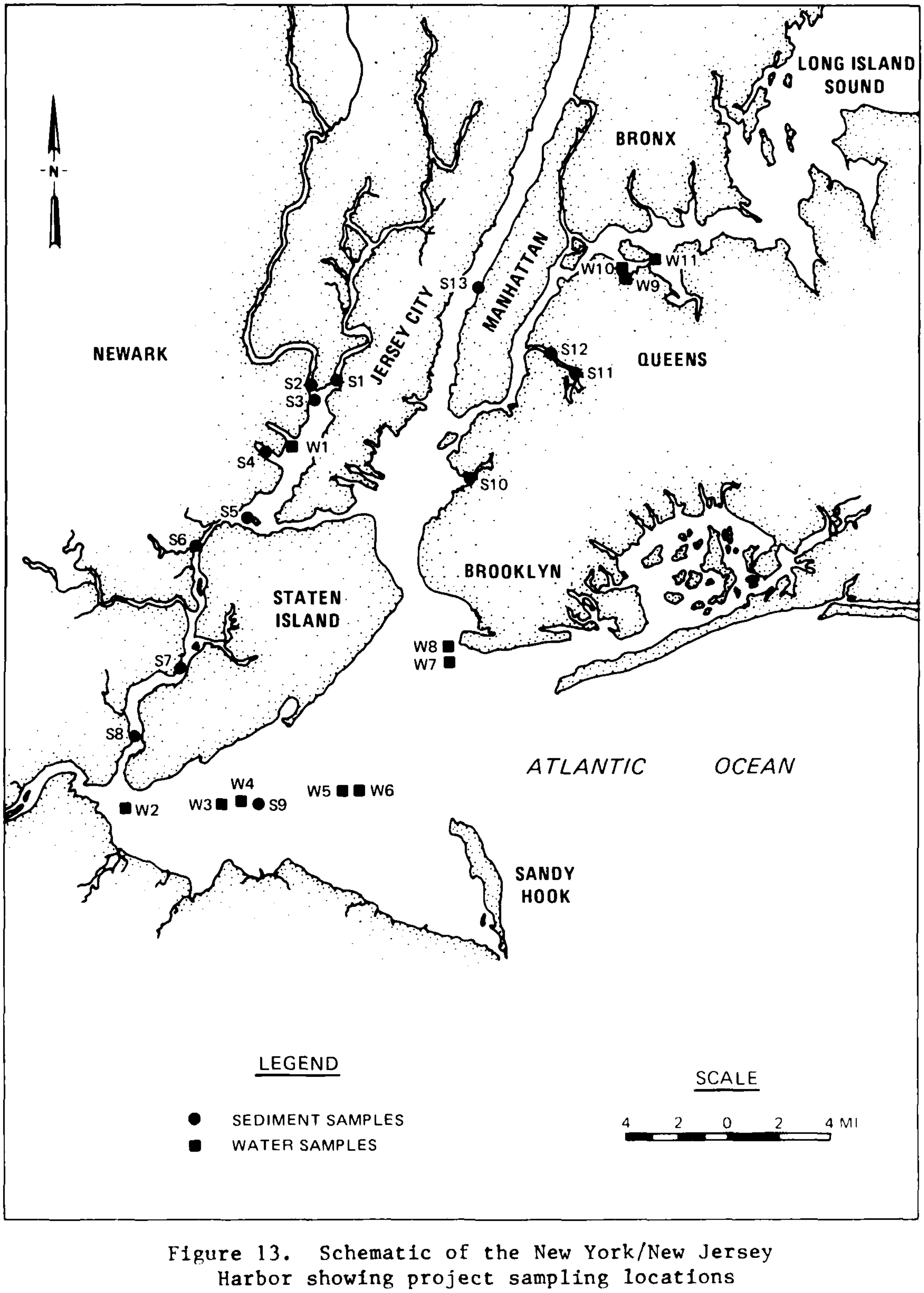


Figure 13. Schematic of the New York/New Jersey Harbor showing project sampling locations

Table 5

Location Descriptions for Sediment Sampling Sites

Site Code	Malcolm Pirnie Site Code*	Location Description	Loran Coordinates
S1	1	Lower Hackensack River. Mid-channel just upstream of large inlet on Kearney Point	L43876.1, L27086.9
S2	2	Lower Passaic River. Approximately 80 ft off Celanese Pier, opposite boom	L43876.3, L27096.0
S3	3	Lower Passaic River, opposite intersection of North Arlington St. and Wallington St., west side of channel	L43872.7, L27094.4
S4	4	Elizabeth Channel. North side of channel opposite easternmost of two large warehouses	L59902.0, L27102.0
S5	6	WNW of Shooters Island. 120 ft north of flashing green buoy "A"	L59890.2, L27102.6
S6	7	Exxon Bayway. 70 ft off pier, opposite second mast from south	L59883.0, L27116.6
S7	9	U.S. Metals. 50 ft off north side of pier, 2/3 of pier length from shore	?
S8**	-	Arthur Kill at Outerbridge Crossing	L43764.3, L27114.6
S9**	-	Raritan Bay West Reach #3. 100 ft SW of R "18" Bell Buoy	L43747.4, L27070.1
S10	-	Upper Gowanus Bay. 80 ft off N. shore of channel, opposite concrete-faced dock in front of Continental Terminals warehouse "D"	L43837.6, L27028.0

(Continued)

* These site codes were used by Malcolm Pirnie, Inc. (1984).

** Samples from these sites were discarded because they appeared to be uncontaminated.

Table 5 (Concluded)

Site Code	Malcolm Pirnie Site Code	Location Description	Loran Coordinates
S11	-	Upper Newtown Creek. North side of channel opposite storm sewer about 100 yd west of Kosciusko Bridge	L43867.7, L27006.5
S12	20	Dutch Kills/Newtown Creek junction. Center of Dutch Kills, level with north shore of Newtown Creek	L43873.6, L27015.3
S13	22	Between Piers 98 and 99. Midway between piers, 50 ft inshore from end of piers	L43898.8, L27045.9

Water sampling

44. Water samples were collected using a 2-ℓ Nansen bottle sampler. Samples were generally taken at the surface, middepth, and channel bottom at each sampling location to determine salinity. The salinities of all water samples were measured in the field using a refractometer. Table 7 shows the salinities as a function of depth at each location. At each site, an additional 1-qt water sample was taken from a 20-ft depth or near the bottom, whichever was shallower. These samples were to be used for chemical analysis in the modified elutriate test and were therefore stored in 1-qt glass jars with Teflon-lined lids. As soon as the jars were sealed and labelled, they were placed in the cooler.

45. At the end of each day's sampling, all sediment and water samples were transferred to refrigerators in the CE water quality laboratory. The samples were stored in the refrigerators at approximately 40° F (4° C).

Shipment and Storage of Samples

46. The sediment samples collected in the New York/New Jersey Harbor were shipped to WES for all laboratory testing. Because of the potential contaminants in the various samples of sediment and because of the types of laboratory testing to be performed on the samples, the sediments were shipped by

Table 6

Location Descriptions for Water Sampling Site

Site Code	Location Description	Loran Coordinates
W1	Port Newark Channel. Approximately 250 ft north of a point 2/3 of the way from C "3" buoy to "I" buoy	L59904.0, L27094.2
W2	South Amboy Reach. Southwest edge of channel, bearing 235° from flashing #"4" buoy	L43743.4, L27114.9
W3	Raritan Bay West Reach. Adjacent to C "25" buoy	L43749.0, L27077.1
W4	Raritan Bay West Reach. Midway between C "25" and #"19" buoys	L43747.1, L27072.1
W5	Ambrose Channel. 200 yd north of #"18" buoy	L43772.1, L27017.5
W6	Ambrose Channel. Between #"14" and #"12" buoy	L43758.4, L27010.8
W7	Raritan Bay East Reach. Adjacent to #"6" buoy	L43732.1, L27030.0
W8	Raritan Bay East Reach. Adjacent to #"8" buoy	L43734.8, L27035.2
W9	Entrance to Bowery Bay	L43893.3, L36994.0
W10	Rikers Island Channel. At entrance to Bowery Bay	L43894.4, L26994.2
W11	Flushing Bay. At end of short pier off NE/SW runway	L43894.6, L26986.1

refrigerated truck; the truck's refrigeration unit maintained a temperature of 39° F throughout the trip. Until laboratory testing could begin, both the sediment and water samples were stored in their sealed containers. These sealed containers were kept in a cold storage room in which the temperature was maintained at 40° F.

Preparation for Laboratory Testing

47. Before the sediment samples could be used for either physical or chemical laboratory testing, they had to be homogenized into a single mixture. The bulk samples to be used for physical analyses were homogenized using a

Table 7

Salinities at Water Sampling Stations

Station Code	Surface Salinity, ppt	Middepth Depth, ft	Middepth Salinity, ppt	Bottom Depth, ft	Bottom Salinity, ppt
W1	--	--	--	--	--
W2	26.5	12	26.5	25	28.5
W3	28.5	12	28.5	20	28.5
W4	28.5	13	28.5	29	28.5
W5	27.5	15	30.5	30	32.5
W6	28.5	15	28.5	33	31.0
W7	28.5	14	28.5	29	31.0
W8	28.5	12	28.5	25	28.5
W9	26.5	--	--	9	26.5
W10	26.5	10	26.5	19	26.5
W11	26.5	12	26.5	24	26.5

steam-cleaned mortar mixer. Approximately 1 qt of material was reserved from each 5-gal bucket for water content determination and specific gravity analysis. The remainder of the material was poured into the hopper of the mortar mixer. Once the buckets had all been emptied into the mortar mixer, the sediment was thoroughly mixed. The homogenized mixture was then poured out of the mixer into two 55-gal steel drums with chemically inert plastic liners. The sediment from one drum was used for microbial analysis, whereas the other drum of material was used for both column settling tests and soil properties tests. Two 5-gal buckets of sediment from each site were used; the wet weights from each site varied, but were generally close to 90 lb. Table 8 shows the wet and dry weights of sediment from each sampling location included in the homogenized mixture. When not in use, the drums were kept sealed with gaskets and lids that were attached by bolted retaining rings. The drums were stored in the cold storage room mentioned previously.

48. The 1-qt samples collected for chemical analysis were also homogenized into a single mixture. The quantities of sediment from each site were carefully regulated so that this mixture contained the same proportions from

Table 8

Weights of Individual Sediment Samples Included in the Homogenized Mixture

Site Code	Wet Weight* of Sediment in Homogenized Mixture, lb	Dry Weight of Sediment in Homogenized Mixture, lb
S1	104.2	40.9
S2	87.9	28.6
S3	93.2	34.0
S4	84.8	28.1
S5	82.6	24.1
S6	83.6	25.8
S7	85.9	27.8
S8	0.0	0.0
S9	0.0	0.0
S10	81.3	23.9
S11	88.2	32.5
S12	89.8	25.9
S13	90.2	39.9

* Two 5-gal buckets of sediment from each site were used. The weights of sediment in each bucket varied somewhat.

each site (as shown in Table 8) for the physical properties analysis. The mixing was performed in a glass bowl using a Teflon-coated stirring propeller. The sediment mixture was then used for the bulk sediment chemical analysis and for the modified elutriate test.

49. The 1-qt water samples that had been taken either (a) at a 20-ft depth or (b) near the bottom of the water body (whichever was shallower) were mixed. This water mixture was then used in the modified elutriate test.

PART IV: MICROBIAL PATHOGENS

Background

50. The kinds and numbers of microorganisms present in bodies of water are dependent upon the presence of many factors, including: types of nutrients, temperature, light, salinity, pH, industrial and animal pollution, and the presence of microbial predators (Alexander 1971, Colwell et al. 1975). The presence of a large number of pathogenic microorganisms does not in itself place any segment of the human population at risk to infection and disease. However, a real danger to humans occurs when water used for drinking or recreational activities has become contaminated by human or animal fecal materials and is ingested (Pelczar and Reid 1964, Colwell et al. 1975).

51. Many pathogenic bacteria can be transmitted from one person to another through fecal contamination of water. Examples of waterborne diseases of bacterial origin include: *Salmonella* (enteritis), *Salmonella typhosa* (typhoid fever), *Shigella* (dysentery), and *Vibrio cholerae* (cholera). The organisms causing these diseases do not normally occur in numbers large enough to permit routine testing of food and water for their presence. However, some intestinal organisms do occur in numbers abundant enough to permit detection by appropriate techniques; among these are *Escherichia coli*, *Streptococcus faecalis*, and *Clostridium perfringens*. Since the presence of these organisms indicates the possibility of contamination by the less frequently occurring pathogenic organisms, these three bacterial species are often used as "indicator species" (Colwell et al. 1975).

Effects of Dredging

52. Survival of pathogenic microorganisms or of bacterial species indicative of the presence of pathogenic microorganisms in sediment is important during dredging and following confined disposal of the material. Disturbing a pathogen-containing sediment and placing it into an environment where pathogens may be mobilized may place a portion of the human population at risk--either through direct contact with the pathogens or through ingestion of contaminated food. A pathogen-containing sediment at the bottom of a

harbor may or may not cause a problem. The same sediment placed into a confined disposal area has an increased potential to cause problems.

53. Microorganisms are known to become associated often with sediment and subsequently to settle to the bottom with the settling sediment particles. However, during the disposal process, fine-grained pathogen-laden sediments and pathogens that have become separated from the sediment by disturbances caused by dredging and disposal activities can be suspended in the water column of the disposal facility; as long as they survive, these organisms remain available for release along with CDF effluents.

54. The behavior of microorganisms in a CDF or under conditions simulating a CDF has never been examined. For this reason, it is not possible to predict if microorganisms in general, and pathogenic microorganisms in particular, settle to the bottom of the CDF or remain suspended in the water column in levels that should be of concern in design and operation of the CDF. To perform this assessment, researchers at WES conducted a settling test that is a modification of one previously developed by the Environmental Laboratory, WES (US Army Corps of Engineers (USACE) 1985). In this test, total fecal coliforms and total fecal streptococci were used as species indicative of the behavior of pathogenic bacteria. To determine if the behavior of these two indicator species is also characteristic of microorganisms in general, the settling pattern of total heterotrophic microorganisms was also followed.

55. If the pathogens remaining with the settled sediment are able to survive for prolonged periods in the CDF environment, these organisms may later be available for release into ground waters (if not filtered out by underlying soils) or for discharge with runoff from the surface of uncovered sediment in the CDF. As was the case with the settling question, this situation has never been examined, and the appropriate testing protocol has never been developed. To determine the capability of pathogens to survive under aerobic conditions, as would be the case in a drying CDF, the survival of total fecal coliforms and total fecal streptococci was examined in a simple shaking-flask study. Because oxidation of sediment under aerobic conditions may sometimes result in a change in sediment pH, the survival of these organisms under three different pH conditions was also examined. Again, the number of total heterotrophic microorganisms was used as an indication of what may be expected to happen with the microbial community as a whole. The results of this investigation may also identify steps that can be taken during

construction and operation of the CDF to minimize the circumstances that promote the mobilization and survival of these organisms in the project.

56. The purpose of this investigation was to assess the kinds and relative abundance of microbial pathogens initially present in the New York/New Jersey Harbor sediment and, using appropriate indicator microorganisms, assess the survival of pathogens during and after disposal. An additional objective was to provide guidance on the most suitable measures for minimizing the mobilization and survival of these organisms during project construction and operation.

Materials and Test Methods

Microbial characterization of sediment

57. The following procedure was used to identify and quantify the pathogenic and indicator bacteria initially present in the New York/New Jersey Harbor sediment. These determinations were made on the sediment within 3 weeks of receipt. Except where otherwise indicated, the same preparative procedures were used for all tests. Instant Ocean sea-salt mix and reverse osmosis water were used to prepare a salt solution having a salinity of 20 ppt. Sufficient New York Harbor sediment was added to each dilution bottle containing 90 ml of sterile 20-ppt water to give a final volume of exactly 100 ml. This mixture was shaken and then used as a source of inoculum for each of the specific media. Ten-millilitre samples of the mixture were also taken for a determination of the concentration of sediment present in the dilution medium. *Salmonella* spp. were determined on selenite cysteine broth and bismuth sulfate agar following initial incubation of the inoculum in lactose broth. The presence of *Vibrio parahemolyticus* was determined using trypticase citrate bile salts (TCBS) agar. *Shigella* spp. were assessed on xylose-lysine-desoxycholate (XLD) and desoxycholate (DC) agars following incubation in GN broth. *Escherichia coli* was detected on eosin methylene blue (EMB) agar following initial cultivation in lactose broth and transfer to brilliant green lactose bile (BGLB) broth. Fecal streptococci were determined on KF Streptococcus agar following initial growth in azide dextrose broth.

58. The dilution procedure was modified for the detection of *Clostridium perfringens* and *Clostridium botulinum*. Between 0.5 and 1.0 g of New York/New Jersey Harbor sediment was added directly to 10 ml of 0.01 M

phosphate-buffered saline using the procedure of Attwell and Colwell (1981). This suspension was sonicated (150 w for 10 sec). The presence of *Clostridium perfringens* was determined with the mCP membrane filter procedure of Bisson and Cabelli (1980). Following incubation at 45° C for 18 to 20 hr in an anaerobic Gas Pak system (BBL Microbiology Systems, Cockeysville, Md.), colonies growing on the filters were subjected to concentrated NaOH fumes to turn acid phosphatase positive colonies red. To detect *Clostridium botulinum*, a sonicated suspension of 1.0 to 2.0 ml was introduced into tubes of cooked meat medium and trypticase-peptone-glucose-yeast extract broth with trypsin (TPGYT); incubation and examination were carried out according to the methods described in the Bacteriological Analytical Manual (Food and Drug Administration (FDA) 1978).

Settling tests

59. Sedimentation tests for microbial evaluation were conducted using the standard 8-in.-diam by 8-ft-tall settling column designed for dredged material settling tests (Montgomery 1978), as described in Engineer Manual 1110-2-5027 (USACE 1987). The apparatus was modified to replace the stopcocks and tubing previously used for sampling ports with ball valves and bulkhead fittings. This modification permitted samples to be taken with a syringe rather than by draining water from a stopcock, thus eliminating small currents created during sampling as a source of disturbance to the settling process. A 20-ppt saltwater mixture was prepared using reverse osmosis water and Instant OceanTM sea-salt mix and was permitted to age overnight. Freshly mixed New York/New Jersey Harbor sediment was added to the aged saltwater mixture to obtain a slurry containing approximately 150 g/ℓ (dry weight) of sediment. The slurry in the preparation tank was stirred constantly while being transferred into the sedimentation column at a rate of 5 ℓ/min. Once in the column, the slurry was held in suspension by the constant addition of air through the bottom sparger plate. The column was filled to a depth of 2.15 m, the maximum level permitted by the frothy nature of the aerated slurry.

60. At this time, initial (time-0) 60-ml samples were taken from each of the top, middle, and bottom ports of the sediment column using a 10-ml syringe equipped with a 14-gage, 30-cm-long steel cannula. Sediment concentrations were assessed by filtering triplicate 10-ml portions of each sample through tared, prewashed, preashed Whatman 944-AH glass microfibre filters (particle retention size, 1.5-μm). The filters were then washed three times

with 10-ml volumes of double-distilled water and dried for 3 hr at 105° C. The remainders of the three samples were pooled in a sterile plugged 150-ml Erlenmeyer flask and then used for microbial enumeration. At this time, the air supply to the bottom sparger plate was terminated, and the settling study was initiated. After 1 hr, three samples were removed from the top port and treated in the same manner as described for the time-0 samples. Sampling at the top port continued until the surface of the settling sediment fell below the next port (after 3 hr), at which time sampling was expanded to include the second port. The process of sampling all ports exposed by the settling sediment was continued at each sampling interval. Samples were taken at 0, 1, 2, 3, 6, 12, 24, 48, 72, and 96 hr.

61. Samples for enumeration of microorganisms were diluted in sterile 20-ppt seawater blanks. Total heterotrophic microorganisms were assessed by pour plating on Standard Methods agar made up with 20-ppt seawater. Total fecal coliforms were determined with a most probable number (MPN) method using lauryl tryptose broth according to Standard Methods (American Public Health Association (APHA) 1980). All positive tubes were subjected to the confirmed test, and atypical colonies obtained on EMB agar were isolated and verified using routine microbiological procedures. Total fecal streptococci were enumerated with an MPN procedure using azide dextrose broth followed by confirmation on KF Streptococcus agar.

62. Sediment concentrations in the water column at each of the time intervals were assessed by determining the difference between the dried empty filters and the same oven-dried filters containing the sediment filtrate. The portion of the sediment weight contributed by inorganic matter was then determined by measuring the sediment weight remaining after the filters had been ashed for 3 hr at 550° C.

63. The settling test was run three times. Data were analyzed by running linear regressions on each parameter against time and on the depth-averaged concentration of microbial species present at a given time against the depth-averaged sediment concentration at that same time.

Survival tests

64. Tests to determine the ability of pathogens to survive under aerobic conditions expected in a drying CDF were run in sediment suspended in water at a salinity of 20 ppt. A slurry containing 150 g (dry weight) of New York/New Jersey Harbor sediment per litre of aged seawater was prepared

and stirred for 15 min. Then, 100-ml quantities of this mixture were placed into sterile 250-ml Erlenmeyer flasks. The pH of each flask was measured, and the values were adjusted to 6.0, 7.0, or 8.0 using either 1.0 N KOH or 1.0 N HCl. The setup for each pH was prepared in triplicate. Following removal of initial (time-0) samples, the Erlenmeyer flasks were plugged and then placed into a shaking water bath at 20° C and 150 rpm.

65. Initial samples were taken with the following procedure. Using a sterile disposable 10-ml pipet, 20 ml of each sediment suspension was removed and placed into a sterile, capped 125-ml culture flask. An additional 20-ml sample was taken and added to a dilution bottle containing 90 ml of sterile 20-ppt seawater. Total fecal coliforms, total fecal streptococci, and total heterotrophic microorganisms were each determined in the same manner as for the sedimentation tests. Additional samples were taken at 3, 7, and 10 days of incubation. The pH value of each flask was checked on a daily basis and adjusted, if necessary, to maintain the pH at the value set on the first day of the study.

66. Results of completed tests were analyzed for numbers of each of the various groups/species of microorganisms against time, and linear regressions were run to determine the rate of decrease or the lack of any decrease for each of the groups of microorganisms studied.

Results of Testing

Microbial characterization of sediment

67. Isolation procedures were successful in demonstrating the presence of the following microorganisms in the quantities indicated per gram dry weight of New York/New Jersey Harbor sediment:

a. *Escherichia coli*--18,200.

b. *Streptococcus faecalis*--32,250.

c. *Clostridium perfringens*--650,000.

d. Total fecal coliforms--66,000.

e. Total fecal streptococci--32,250.

f. Total heterotrophic bacteria--1,270,000.

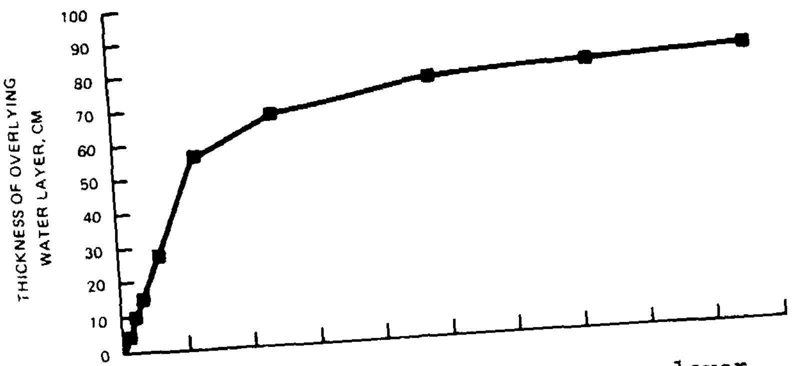
Salmonella spp., *Shigella* spp., and *Clostridium botulinum* were not isolated. However, failure to isolate a given pathogen does not mean that the pathogen is not present, only that the pathogen was not isolated.

Settling test results

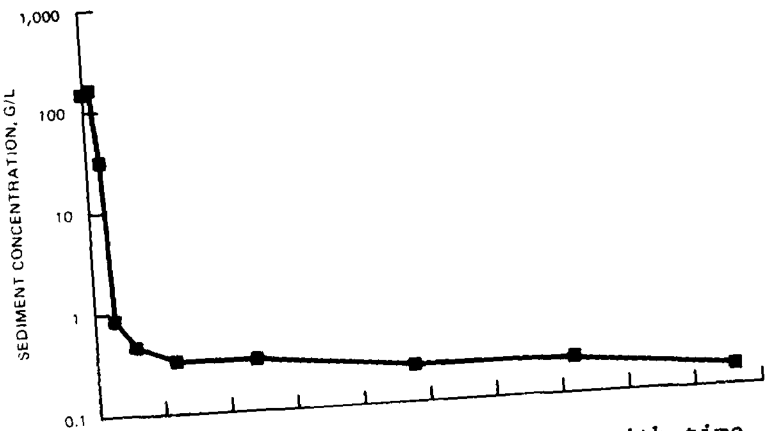
68. Changes observed in sedimentation in the settling columns during the course of the settling test are presented graphically in Figure 14 and numerically in Table 9. The level of the sediment surface fell slowly, reaching the first sampling port at the 2-m (6-ft) mark between the second and third hour of the test. The fall of the sediment surface level below the water column surface was extremely linear for the first 24 hr; a linear regression run on the data for the depth of the clear water layer over the sediment surface with time had a coefficient of correlation (r^2) of 0.91. Although the rate of fall of the sediment surface level after 24 hr decreased exponentially with time, a linear regression run on the full 96-hr test had an r^2 of 0.71, indicating a fair linear fit for these data. The mean sediment concentration with time cannot be described linearly because of the manner in which the sampling was done, and a linear regression run on the mean sediment concentration against time over the course of the full 96-hr settling test showed a poor coefficient of determination ($r^2 = 0.38$) as shown in Table 10. With the exception of the time-0 sample, all samples were taken at the first port until the sediment surface layer had passed the second port, at which time sampling of the second port was added to the sampling of the first port, etc. Once the sediment surface layer had passed the first port, the sampling that followed at that port was essentially examining the clarification of the water layer in the region of that port. The settling of the sediment remaining in the clear water behaved in more linear fashion, and a linear regression run on the data starting at the sixth hour of the test gives a line having an r^2 of 0.82.

69. The fraction of the sediment composed of inorganic matter also decreased linearly with time as shown in Figure 14 and Table 10; the line describing this behavior had an r^2 of 0.95. The fact that the weight of the sediment lost during the process of ashing at 550° C was largely organic matter suggests that the particulate inorganic component of the sediment was settling more rapidly than was the organic component.

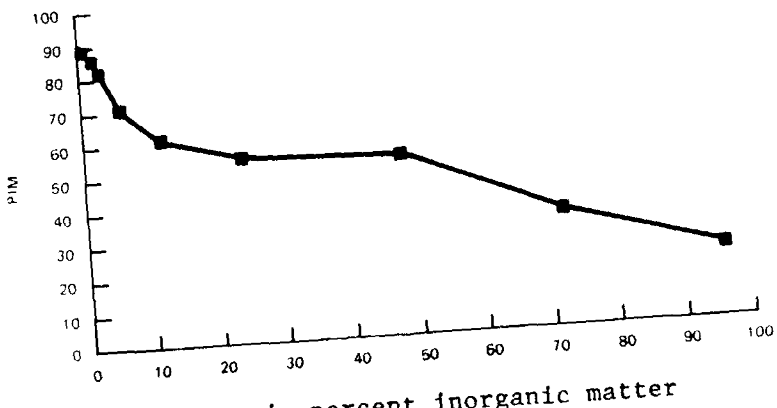
70. During each run, a persistent oily layer formed at the surface of the water column within the first few minutes of the test. Particles were observed settling out of this scum whenever the column was disturbed during the removal of samples. To minimize the impact these settling particles had on the parameters measured and to provide a better estimate of the sediment



a. Change in depth of the clear water layer overlying the settling sediment with time



b. Change in sediment concentration with time (Note: After 3 hr, the sediment being measured is in the clear water layer, not the entire settling column.)



c. Change in percent inorganic matter content of the sediment with time

Figure 14. Changes in properties of the sediment and water column with time during the course of the 96-hr settling test

Table 9

Change in Properties of the Sediment in the Water Column with Time During the Course of the 96-Hr Settling Test

Time hr	Depth of Clear Water Layer over Sediment cm	Mean Sediment Concentration g/ℓ (S.D.)	Sediment Remaining After Ashing percent
0	0.0	154.193* (1.651)	88.5
1	2.5	167.154* (0.097)	88.4
2	8.4	32.223* (1.276)	85.6
3	13.6	0.862 (0.022)	81.7
6	26.1	0.464 (0.146)	70.9
12	54.8	0.332 (0.104)	61.3
24	66.2	0.322 (0.118)	55.0
48	74.6	0.240 (0.095)	53.6
72	77.8	0.233 (0.061	35.0
96	80.0	0.167 (0.069)	22.3

* For the first 3-hr, the sediment layer had not settled past the first sampling port. Thus, samples at 0, 1, and 2 hr contain rather large amounts of sediment relative to later samples.

and microbial levels in mixed effluents leaving the CDF, the values for each parameter were depth averaged for the portion of the settling column sampled at a given time interval. Data were then analyzed by running linear regressions on each parameter against time and on the concentration of each of the microbial species present at a given time against the sediment concentration

Table 10

Comparison of Sediment and Inorganic Composition of Sediment with Time in the Water Column During the 96-Hr Settling Test

Parameter*	Elapsed Time, hr									
	0	1	2	3	6	12	24	48	72	96
Sediment Concentration (g/ℓ)	2.1881	2.2231	1.5082	-0.0645	-0.3348	-0.4789	-0.4921	-0.6918	-0.6326	-0.7773
Linear Regression Equation: $Y = -0.0220x + 0.8324$; $r^2 = 0.3805$										
Concentration of PIM** (%)	1.9469	1.9463	1.9325	1.9121	1.8505	1.7875	1.7406	1.7288	1.5442	1.3487
Linear Regression Equation: $Y = -0.0056x + 1.9215$; $r^2 = 0.9485$										

* Values are expressed as the logarithms of the concentration in the water column at the time intervals indicated.

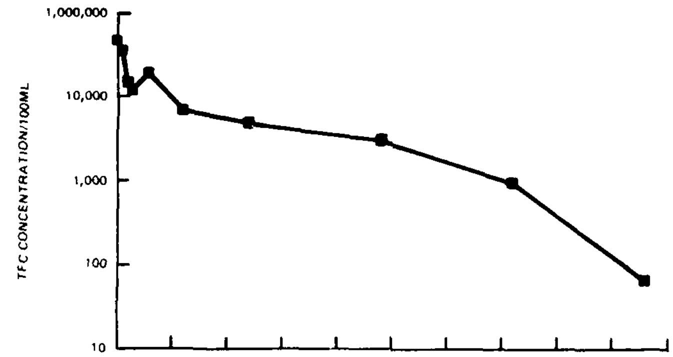
** PIM = particulate inorganic matter.

at that same time. The percent of inorganic matter remaining was also compared with the total sediment concentration in the water column at each time by running a linear regression. Because the sedimentation phenomena observed here were exponential in nature, all concentrations of microorganisms were converted to logarithms before the regressions were performed.

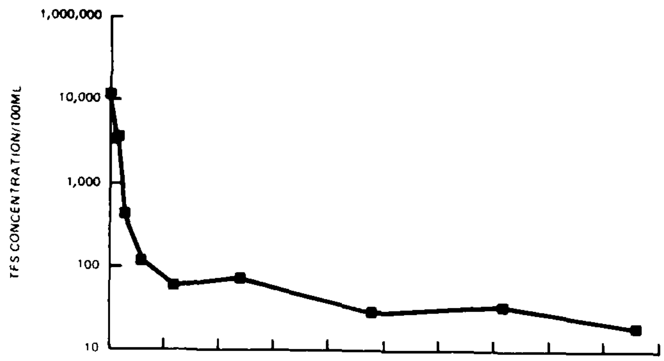
71. The settling of the three groups of microorganisms examined in the settling test is presented in Figure 15 and Table 11. To facilitate comparison of these data, the total heterotrophic microorganisms, which were measured on a basis of the number of organisms per millilitre of fluid, were expressed on a basis of the number of microorganisms/100 ml. That the number of total heterotrophic microorganisms present (19,500,000 organisms/100 ml at time 0) was far in excess of the numbers of either of the two groups of bacteria (total fecal coliforms, 49,667/100 ml at time 0; total fecal streptococci, 12,367/100 ml at time 0) is not surprising because of the more general, less selective nature of the media upon which the total heterotrophic microorganisms were isolated. Regression equations for each of the three groups of microorganisms are presented in Table 11. As indicated in Table 11, good coefficients of correlation were obtained for the levels of total fecal coliforms ($r^2 = 0.84$) and total heterotrophic microorganisms ($r^2 = 0.82$) versus time, and a fair coefficient of correlation was obtained for the levels of total fecal streptococci ($r^2 = 0.65$) versus time. However, for some of the tests, substantial numbers of both total fecal coliforms (71/100 ml) and total fecal streptococci (20/100 ml) remained in the water column at 96 hr.

72. When the levels of each of the three groups were compared with the sediment concentrations in the water column over time, as shown in Figure 16 and Table 12, excellent agreement was found between sediment and total fecal streptococci ($r^2 = 0.93$), fair agreement was observed between sediment and total heterotrophic microorganisms ($r^2 = 0.68$), but a poor coefficient of correlation was obtained between sediment and total fecal coliforms ($r^2 = 0.48$).

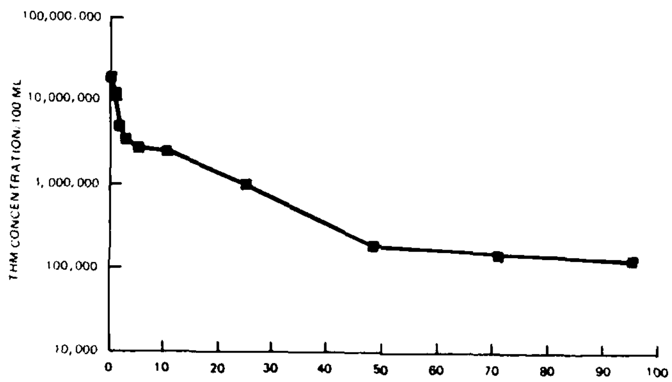
73. An additional observation, but one that was not quantitated, is that the water column at 96 hr retained a yellowish coloration and an oily appearance at the surface. This, coupled with the organic nature of the suspended particulate matter indicated above, suggests that at the 96-hr period when the test was completed, substantial amounts of organic material were present in both dissolved and suspended forms in the water column.



a. Total fecal coliforms (TFC)



b. Total fecal streptococci (TFS)



c. Total heterotrophic micro-organisms (THM)

Figure 15. Changes in levels of micro-organisms in the clear water layer with time during the course of the 96-hr settling test

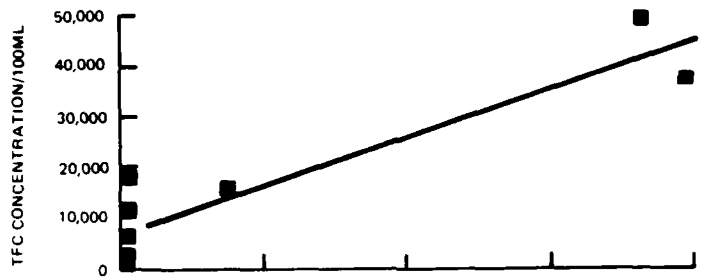
Table 11

Comparison of Microorganisms Remaining in the Water Column During the 96-Hr Settling Test

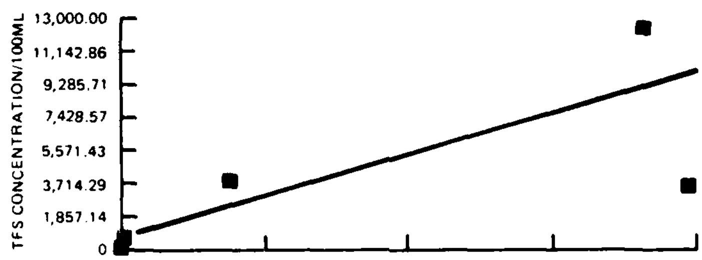
Group* of Micro - organism	Elapsed Time, hr**									
	0	1	2	3	6	12	24	48	72	96
TFC	4.6961	4.5760	4.1663	4.0840	4.2792	3.8349	3.7070	3.4907	3.0077	1.8512
	Linear Regression Equation: $Y = -0.9898x + 4.7151$; $r^2 = 0.74$									
TFS	4.0922	3.5500	3.5729	2.6434	2.0864	1.7853	1.8751	1.4771	1.5563	1.3010
	Linear Regression Equation: $Y = -1.1243x + 3.3966$; $r^2 = 0.87$									
THM	7.2822	7.0902	6.7054	6.5380	6.4422	6.3995	6.0088	5.2636	5.1948	5.1278
	Linear Regression Equation: $Y = -0.0209x + 6.7552$; $r^2 = 0.83$									

* Abbreviations: TFC = total fecal coliforms; TFS = total fecal streptococci; THB = total heterotrophic microorganisms.

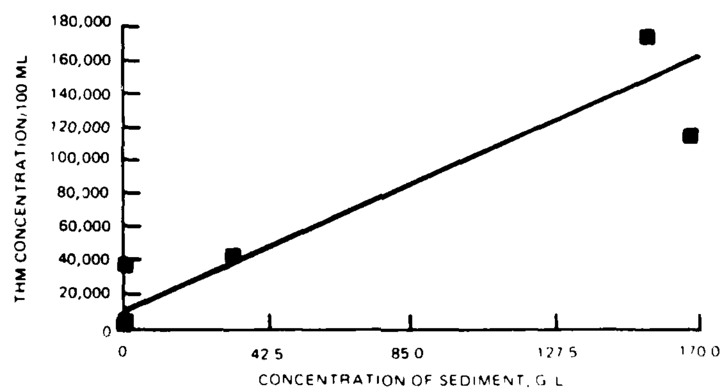
** Numbers given are logarithms of the numbers of microorganisms per 100 ml in the water column at the time indicated.



a. Total fecal coliforms (TFC)



b. Total fecal streptococci (TFS)



c. Total heterotrophic micro-organisms (THM)

Figure 16. Relationship of micro-organisms to sediment concentration in the water column during the course of the 96-hr settling test

Table 12

Linear Regressions* of Changes in Sediment Concentration and Concentrations of Microorganisms with Time During the 96-Hr Settling Test

Sediment Concentration vs**	Linear Regression Equation	Correlation Coefficient (r^2)
TFC	$y = 228x + 6807$	0.84
TFS	$y = 47x + 362$	0.65
THM	$y = 783x + 8304$	0.82

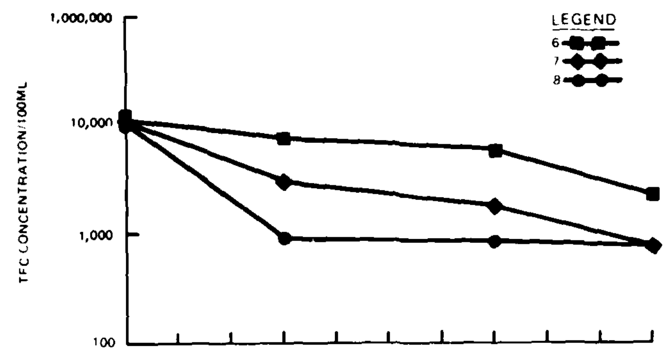
* Regressions were run on the concentrations of sediment and microorganisms in the water column during the settling period.

** Abbreviations: TFC = total fecal coliforms; TFS = total fecal streptococci; and THM = total heterotrophic microorganisms; vs = versus levels of microorganisms (TFC, TFS, THM)

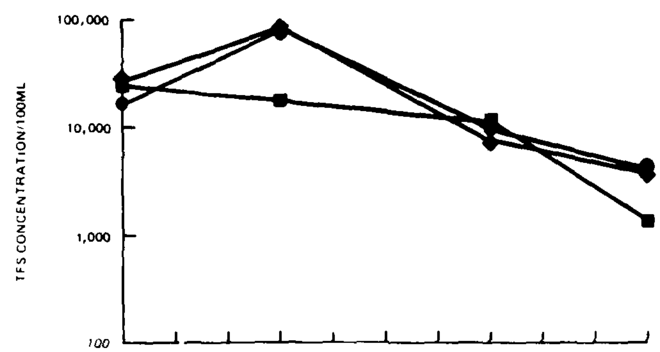
Survival test results

74. The decline in numbers of total fecal coliforms with time is shown in Figure 17 and Table 13. The sediment in this test was held in suspension, rather than being permitted to settle. Therefore, the decline observed here is indicative of an actual decrease in the viable numbers of these organisms rather than a disappearance from the water column, as was the case for the settling test. The highest rate of decrease (a slope of -0.10725) as well as the best linear fit ($r^2 = 0.95$) was obtained at pH 7.0. A somewhat lower rate of decrease (slope -0.09935) and a fair linear fit ($r^2 = 0.62$) were observed at pH 8.0, while the smallest rate of decrease (slope of -0.06352) but a very good linear fit ($r^2 = 0.89$) were observed at pH 6.0. These results indicate larger rates of decrease in numbers of organisms at pH values of 7.0 or above and more persistence at pH 6.0.

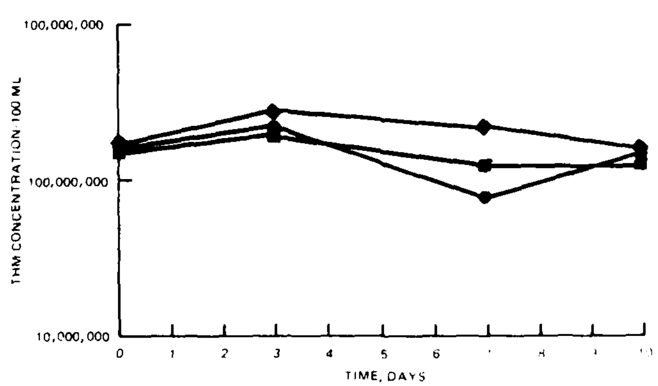
75. The decline in numbers of total fecal streptococci with time is shown in Figure 17 and Table 14. In contrast to the data for the total fecal coliforms, the data for total fecal streptococci exhibit a definite trend towards increased persistence (lower slopes) and poorer linear behavior (decreasing r^2's) with an increase in pH.



a. Total fecal coliforms (TFC)



b. Total fecal streptococci (TFS)



c. Total heterotrophic microorganisms (THM)

Figure 17. Changes in level of microorganisms during the course of the 10-day survival test

Table 13

Die-Off of Total Fecal Coliforms During the 10-Day Survival Test*

pH	Time Elapsed, days: 0	3	7	10
6.0	11,367	7,600	5,933	2,300
	(6,527)	(6,200)	(5,538)	(1,328)
	[4.0556]	[3.8808]	[3.7733]	[3.3617]
	Linear Regression Equation: $Y = -0.06352x + 4.0855$; $r^2 = 0.89$			
7.0	11,050	3,000	1,833	767
	(2,330)	(1,193)	(970)	(767)
	[4.0434]	[3.4771]	[3.2632]	[2.8848]
	Linear Regression Equation: $Y = -0.10725x + 3.6197$; $r^2 = 0.95$			
8.0	10,733	900	857	767
	(6,649)	(440)	(722)	(767)
	[4.0307]	[2.9542]	[2.9380]	[2.8848]
	Linear Regression Equation: $Y = -0.0835x + 4.5985$; $r^2 = 0.46$			

* Values given are the number of organisms per 100 ml and represent the mean of three replicates. Value in parentheses is the standard error of the mean. Value in brackets is the logarithm of the number of organisms per 100 ml.

Table 14

Die-Off of Total Fecal Streptococci During the 10-Day Survival Test*

pH	Time Elapsed, days: 0	3	7	10
6.0	24,000	17,667	11,433	1,367
	(0)	(3,283)	(4,158)	(536)
	[4.3802]	[4.2472]	[4.0582]	[3.1357]
	Linear Regression Equation: $Y = -0.1138x + 4.5243$; $r^2 = 0.79$			
	26,667	83,000	7,533	3,800
7.0	(3,180)	(38,889)	(3,844)	(1,600)
	[4.4260]	[4.9191]	[3.8770]	[3.5800]
	Linear Regression Equation: $Y = -0.1089x + 4.7448$; $r^2 = 0.65$			
	16,667	79,333	9,633	4,167
8.0	(3,667)	(12,667)	(2,436)	(1,233)
	[4.2218]	[4.8994]	[3.9838]	[3.6198]
	Linear Regression Equation: $Y = -0.0835x + 4.5985$; $r^2 = 0.46$			

* Values given are the number of organisms per 100 ml and represent the mean of three replicates. Value in parentheses is the standard error of the mean. Value in brackets is the logarithm of the number of organisms per 100 ml.

76. The total heterotrophic microorganisms showed no definitive decreases with time, and attempts to demonstrate linear behavior ranged from poor (r^2 for pH 6 = 0.36) to nonexistent (for the other two pH values tested) as shown in Figure 17 and Table 15. At all three pH values examined, the numbers of microorganisms found on the third day of incubation increased from those obtained on the first day, suggesting growth of these organisms on the suspended sediment and/or materials dissolved in the water. As was the case for the settling study, the number of microorganisms in this group was several orders of magnitude higher than for the other two groups.

Interpretation of Results

77. An important point needs to be made prior to any discussion of either the settling test or the survival test. Removal of New York/New Jersey Harbor sediment for laboratory testing or for placement into a CDF takes the sediment out of its natural setting. As pointed out previously, this sediment contains large numbers of indicator species and, presumably also, large numbers of pathogens that these organisms indicate are potentially present. However, there are a number of limitations and concerns. The presence of fecal coliforms in water suggests that either animal or human wastes have contaminated the systems and that their associated pathogens may also be present (Moore 1959, McKee and Wolf 1963). Development of indicator standards, prediction of risk of waterborne disease, and measurement of pathogen levels require an understanding of the relationship between indicator and pathogen species. For a given level of indicator organisms, there should be a related level of pathogens under a known set of conditions. This hypothesis is based on the assumption that relatively constant levels of pathogens are present in sewage; this may be true to some extent in large municipal sewage systems, but as the number of individuals contributing to the waste becomes smaller, the indicator to pathogen ratio variation increases (Burton 1985). In addition, fecal coliform indicator validity is dubious in predicting health hazards resulting from the presence of pathogenic protozoa and viruses. Many studies have demonstrated the presence of enteric viruses in waters containing acceptable levels of fecal coliforms (Gerba et al. 1979). Humans do not have a normal viral flora. Also, the relationship of viral levels to fecal coliform levels is made tenuous by several difficulties, including variable

Table 15

Changes in Numbers of Total Heterotrophic Microorganisms During the 10-Day Survival Test*

pH	Time Elapsed, days: 0	3	7	10
6.0	147,000 (24,000) [5.1673]	195,000 (27,700) [5.2900]	124,000 (48,600) [5.0934]	127,000 (8,850) [5.1038]
	Linear Regression Equation: $Y = -0.01225x + 5.2249$; $r^2 = 0.36$			
7.0	166,000 (8,790) [5.2201]	253,000 (56,500) [5.4031]	212,000 (25,900) [5.3263]	155,000 (23,100) [5.1903]
	Linear Regression Equation: $Y = -0.00523x + 5.3110$; $r^2 = 0.05$			
8.0	157,000 (24,400) [5.1959]	213,000 (21,500) [5.3324]	78,700 (32,500) [4.8960]	145,000 (9,020) [5.1614]
	Linear Regression Equation: $Y = -0.0180x + 5.2365$; $r^2 = 0.19$			

* Values given are the numbers of microorganisms per millilitre and represent the mean of three replicates. Value in parentheses is the standard error of the mean. Value in brackets is the logarithm of the number of organisms per 100 ml.

percentage of infected excreters, subclinical infections, inadequate enumeration methods, and varying survival rates (Pipes 1978, Melnick and Gerba 1980, IAWPRC Study Group on Water Virology 1983). Virus survival is reportedly longer than fecal coliform survival; as a result, a ratio between these organisms will change with time and distance from the point of discharge.

78. The relationship of fecal coliform densities in the water column to pathogen densities in sediment is somewhat unclear. Sediment has been shown to be a haven for significantly higher levels of bacteria, viruses, and protozoa, both pathogenic and nonpathogenic, than are found in water (Van Donsel and Geldreich 1971; Winslow 1976; Matson, Horner, and Buck 1978; Gerba et al. 1979; Grimes 1975; Pellet, Bigley, and Grimes 1983). The presence of large numbers of enteric organisms in the sediment suggests that there is or has been some degree of contamination of the overlying water (Allen, Grindley, and

Brooks 1953). In the case of New York/New Jersey Harbor sediment, the original source of the organisms is likely either untreated or poorly treated sewage that was discharged upstream of or within the New York/New Jersey Harbor area. The waters in New York/New Jersey Harbor were not tested for the presence of these organisms. If the CDF containing New York/New Jersey Harbor sediments were being placed in a pristine reservoir that contained no pathogens and also served as a source of drinking water for a city, a great deal of care would need to be taken to ensure that CDF effluents contain little or no pathogens. If, on the other hand, the CDF is going to be placed in New York/New Jersey Harbor and the waters around the CDF already contain pathogens from the previously mentioned sewage effluents, the density of pathogenic microorganisms in the CDF effluents may actually be lower than those present in the ambient waters. Therefore, it is very important that levels of this microorganism be determined in the waters around the site.

Microbial characterization of sediment

79. The failure to demonstrate the presence of pathogenic microorganisms in New York/New Jersey Harbor sediment is not particularly surprising in view of past experiences by other investigators in this area. As discussed previously, inability to isolate a specific organism does not mean the organism is not present; it merely means that the organism could not be isolated. Nonetheless, it was important to conduct this investigation before proceeding with the other studies. If efforts to detect one of the other pathogens had been successful, it would have been worthwhile to follow the progress of that specific pathogen in the other tests. It is also important that the presence of both *Escherichia coli* and *Streptococcus faecalis* was demonstrated, because these are key indicator species, and the progress of these organisms was easy to follow in the settling and survival tests. The use of *Clostridium perfringens* as an indicator species was not pursued, because the complicated procedures necessary for isolating this organism did not lend themselves readily to routine processing of large numbers of samples. It would also have been desirable to sample the entire sediment column each time a sample was taken during the settling test, but the tremendous quantities of media and the labor-intensive effort required to conduct the sampling that was done represent the maximum effort that could be sustained within the time and financial constraints of this study.

Settling test

80. The settling test indicated that given enough time and a lack of circulation in the water column over the settling sediment, the indicator species examined will eventually settle out of the water column. Use of linear regression equations computed as a result of these studies enables predictions to be made for the time periods necessary to achieve a level of 0 for each of the organisms. However, the times involved are extremely long (approximately 5,300 hr for the total coliform count and 187 hr for the total fecal streptococci count). It is highly unlikely that this length of time will pass without some disturbance of the water column occurring.

81. The drinking water standard in the United States is 1 total coliform/100 ml. At 96 hr, the level of total coliforms in the water column of the settling test exceeds this standard. In an estuarine or marine situation, application of drinking water standards for the levels of total fecal coliform or total fecal streptococci appears to be inappropriate. The drinking water standard is supported by over 60 years of epidemiological evidence, whereas the application of indicator microorganisms for assessing the microbiological quality of surface waters has no such foundation (Olivieri, Kawata, and Kruse 1978). The level of total fecal coliforms in the settling test water column at 96 hr does meet the 200-fecal coliform MPN/100-ml standard of the National Technical Advisory Council (1968), indicating an acceptable quality for water contact recreation, if such were to be permitted.

82. An additional set of standards that must be applied are those of the Interstate Sanitation Commission. The Commission's effluent standards for fecal coliforms are 200 organisms/100 ml on a 30-consecutive day average; 400 organisms/100 ml on a 7-consecutive day average; and 800 organisms/100 ml on a 6-consecutive hour average. No sample may contain more than 2,400 organisms/100 ml. In addition, as of 1 July 1986, the Commission's amended water quality standards require year-round disinfection of all effluents into waters of the Interstate Sanitation District where the proposed containment islands will be sited.

83. Some caution must be observed when interpreting the results presented here. Any microbial enumeration method has its limitations. There are two predominant standard methods for indicator enumeration. The membrane filtration (MF) method is more popular than the MPN method because of its

simplicity; however, the MPN method permits greater recovery from chlorinated waters (Schiemann 1978). MPN methods have wide ranges around the values that are determined by the test. The five-tube test used here is more statistically accurate than the simpler three-tube test. By way of example, an MPN test giving an MPN Index of 2 organisms/100 ml has 95-percent confidence limits of from <0.5 to 7 organisms/100 ml; an MPN Index of 22 organisms/100 ml has 95-percent confidence limits of from 7 to 67 organisms/100 ml (APHA 1980). In addition, the study also had limitations with respect to the freshness of the samples used. Desirably, a study examining the microbial populations present in a sediment should examine the sediment within a few hours of its collection. However, the time and facilities required to conduct this study did not permit immediate analysis of the sediment. The phenomena observed and the rates computed are probably correct. However, the time that elapsed between sample collection and analysis undoubtedly allowed die-off of the sediment bacteria to occur. Because precautions were taken to keep the sediment refrigerated and analyses were performed within a reasonable period, the amount of die-off should have been minimal.

84. Another word of caution is necessary with respect to the filters used in the settling test. The exclusion size of the Whatman Glass Microfibre Filters used is 1.5-μm. This fiberglass filter was selected because it is specified in Standard Methods (APHA 1980) for the determination of "nonfilterable residue" (formerly known as suspended solids). The 1.5-μm pore size of this filter is far above the 0.45-μm pore size commonly used to distinguish between dissolved and particulate matter. However, at the present time, the pore-size boundary between dissolved and particulate matter and even between living and nonliving matter is under much dispute. Some investigators feel that because bacteria in some systems are able to pass a 0.22-μm filter, the dissolved portion of a sample should be set at that fraction passing a 0.10-μm filter (Blum and Mills 1986); others feel that a 0.10-μm filter should be used to separate colloidal from dissolved matter, with 0.45-μm being the separation point between particulate and colloidal matter (Kennedy, Zellweger, and Jones 1974). In any case, the 1.5-μm filter used here cannot be said to remove bacteria, other than those organisms attached to particles trapped by the filter.

Survival tests

85. Many studies have examined the survival rates of fecal coliform and pathogenic bacteria in water (Carter, Whaley, and Carpenter 1967; McFeters and

Stuart 1972; McFeters et al. 1974). When enteric organisms such as coliforms and pathogens enter nutrient poor aquatic systems, they become physiologically stressed (Bissonette et al. 1975). Many factors affect survival, including: sunlight, pH, protozoa, phage, and metal and organic toxicants (Mitchell, Yankofsky, and Jannasch 1967; Van Donsel, Geldreich, and Clark 1967; Faust, Aotaky, and Hagadorn 1975; Kapuscinski and Mitchell 1983). It is apparent that indicator organisms die off more quickly in marine waters than in freshwater systems (Chamberlain and Mitchell 1978, Dufour 1984). Many studies have shown that fecal streptococci survive longer than fecal coliforms in surface waters, ground waters, and sediments (Saylor et al. 1975; Keswick et al. 1982; Miescier and Cabelli 1982, Fattal et al. 1983). One subgroup of fecal streptococci, the enterococci, has been shown to survive longer than other fecal streptococci (McFeters et al. 1974, Geldreich et al. 1980). Their survival is more indicative of virus survival; for this reason, these may be the best indicators of waterborne disease (Cabelli 1981, 1983; Keswick et al. 1982; Miescier and Cabelli 1982; Cabelli et al. 1983; Fattal et al. 1983).

86. Sediments greatly extend the survival of most microorganisms having sanitary significance, as indicated by the higher numbers of these organisms in sediment when compared with water. However, there are few actual studies of survival in sediments (Van Donsel and Geldreich 1971; Chan, Wong, and Mak 1979). Thus, there is little with which to compare the results of the studies presented here.

87. The survival tests demonstrate that under aerobic conditions with constant agitation at 20° C, there are predictable declines in the levels of total fecal coliforms at all pH values tested. Likewise, there are also predictable declines in the levels of total fecal streptococci at pH 6.0 and 7.0, but not at pH 8.0. The tendency for fecal coliforms to die off readily at pH 7.0 and above may help explain the poor correlation between decrease in numbers of these organisms with decreasing sediment levels, as shown in Figure 14 and Table 9; i.e., the decreases observed in total coliform levels were likely due more to die-off than to settling of organisms with the sediment. However, it is important to note that within a short period after the air supply to the sedimentation column had been terminated, the water column may have become anoxic. While the dissolved oxygen levels in the settling column were not monitored, the failure of the sediment to acquire the lighter color characteristic of oxidized sediment in the survival tests indicates either that

dissolved oxygen was not present for very long or that dissolved oxygen levels remaining in the water column were very low. Under anaerobic conditions, the pH tends to remain at or near neutrality (Brannon et al. 1978). The lack of a decline in numbers of heterotrophic microorganisms signifies that conditions in the test systems were not necessarily toxic to all microorganisms. The observed increase in numbers of heterotrophs indicates that either these organisms were able to multiply or else some factor or factors previously inhibitory to the organisms were being removed. Additional and more sophisticated tests are required to determine the exact cause of the increase.

Significance of Results to Disposal

88. In a literature review on the density levels of pathogenic organisms in municipal wastewater sludges, Pederson (1981) delineates the "Part 257 criteria" set forth by the US Environmental Protection Agency (USEPA) in 40 CFR Part 257 (Federal Register, Vol 44, No. 179, 13 September 1979). These are summarized here as an example of the minimum treatment requirement for municipal wastewater treatment sludges prior to land application of the residue.

- a. Aerobic digestion. The sludge is to be agitated under aerobic conditions from 60 days at 15° C to 40 days at 20° C, with a volatile solids reduction of a minimum of 38 percent.
- b. Air drying. The liquid sludge is to be drained or dried on sand beds with underdrains or basins with a sludge depth of 22.9 cm for 3 months, 2 months of which must have temperatures averaging above 0° C on a daily basis.
- c. Anaerobic digestion. The sludge is maintained in the absence of air from 60 days at 20° C to 15 days at 35° to 55° C, with a volatile solids reduction of a minimum of 38 percent.
- d. Composting. The sludge may be composted using within-vessel, static aerated, or windrow methods at 40° C for 5 days, with the requirement that during this period, the temperature must exceed 55° C for 4 hr.
- e. Lime stabilization. The sludge must receive lime application in quantities sufficient to produce a pH of 12 after 2 hr of contact.

89. These criteria are presented as examples of the extreme precautions that can be taken if the USAED, New York, should wish to be absolutely certain that New York Harbor sediment is safe for land application. However, while this sediment did contain high levels of coliform bacteria and fecal

steptococci, the concentrations found in this work do not begin to approach the density levels of organisms commonly found in raw sludge and septage; here, levels of 10^5 to 10^8 organisms/g dry weight are observed (Pederson 1981).

90. The principal concern in this study with respect to placement of New York/New Jersey Harbor sediment into a CDF was the retention time for the CDF effluent. With the Interstate Sanitation Commission's requirement that all effluents be chlorinated (paragraph 82), the concentration of coliform bacteria in the effluent is of concern only with respect to the nature (i.e., chlorine, ozone) and amount of treatment substance required for disinfection. Obviously, the longer the retention time of water in the CDF, the lower will be the level of coliforms available for release. It is important that the method of treatment be selected with care. The scope of this study did not include an examination of all potential impacts associated with possible disinfection measures. Care must be taken in the selection of any treatment measure to ensure that undesirable by-products are not produced. Two groups of compounds may result from chlorination of water containing contaminants. Chlorination of water containing dissolved organic compounds may produce trihalomethanes, and one observation of this work was that a large amount of organic matter of an undescribed nature remained in the water column, even at 96 hr. These compounds are known carcinogens and may have deleterious impacts on man or the aquatic biota. Chlorination of ammonia, released from suspended sediment, may produce chloramine compounds; these are stable, toxic, and carcinogenic. Finally, any remaining free chlorine, while relatively unstable, is capable of killing substantial numbers of organisms, especially planktonic forms. Selection of specific treatment measures or substances, while an important consideration, is outside the scope of the present study. It is suggested that this consideration be pursued as a part of a Phase II investigation.

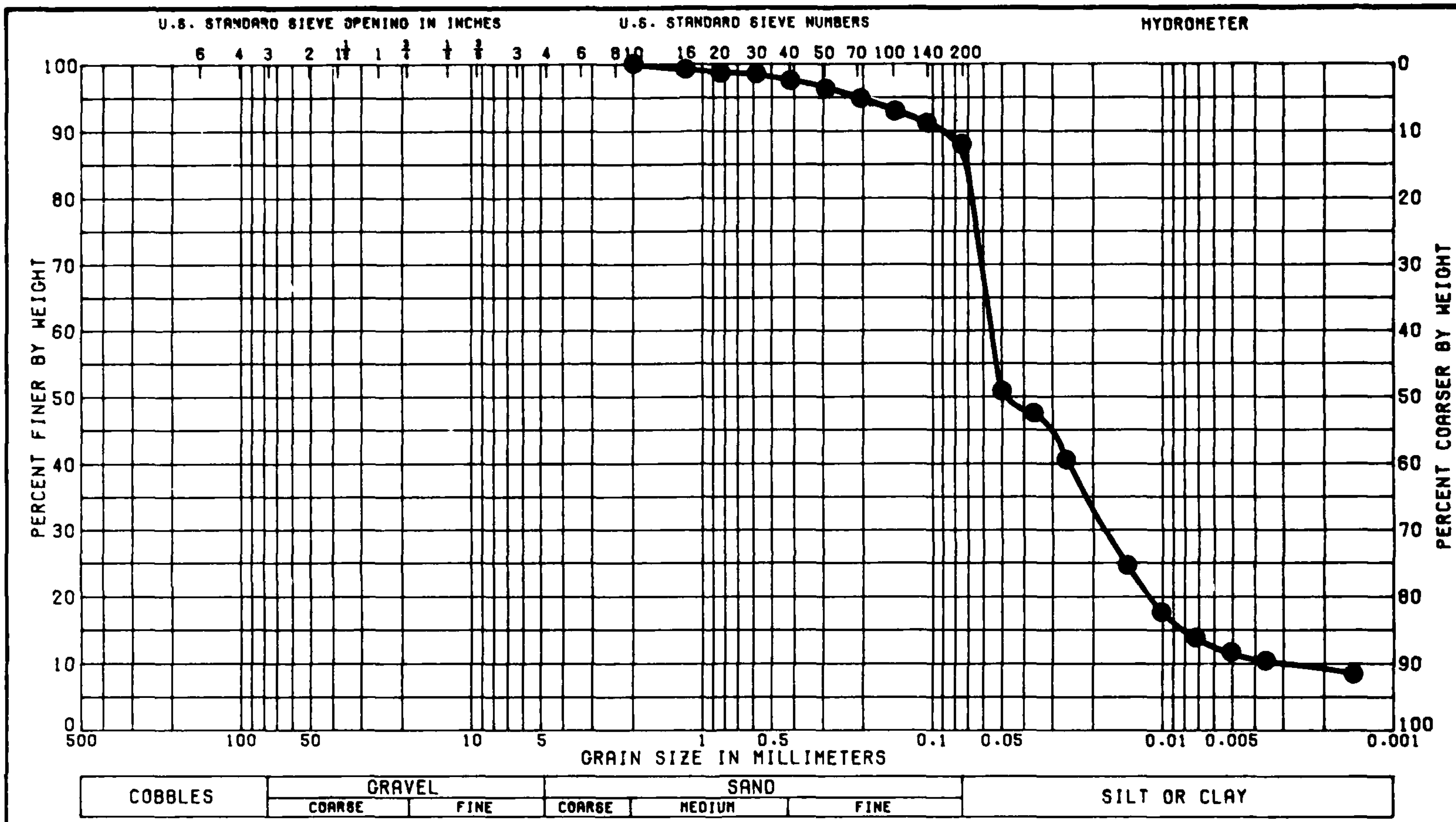
PART V: LABORATORY TESTING FOR EFFLUENT QUALITY AND STORAGE CAPACITY EVALUATIONS

91. The sediment collected from the New York/New Jersey Harbor was subjected to a variety of laboratory tests to obtain data necessary for an evaluation of effluent quality and storage capacity of the confined disposal alternatives. These tests were designed to characterize both the physical and the chemical behavior that could be expected during and after dredging disposal operations. Physical characterization tests were run to predict the physical behavior of the material. Standard soils tests were performed to classify the sediment as to material type, and three types of sedimentation tests were run to determine the settling characteristics of the sediment. In addition, consolidation tests were performed to determine the compressibility characteristics of the material. When the sediment to be tested is suspected to be contaminated, tests are required to evaluate potential contaminant release; therefore, the modified elutriate test was performed to provide an estimate of effluent chemical quality.

Physical Classification

92. The individual sediment samples collected from the New York/New Jersey Harbor were combined to form a bulk sediment sample that was stored in two 55-gal drums until it was required for testing classification. A drum of material was then thoroughly mixed, and a representative portion of the material was submitted to the WES Geotechnical Laboratory for physical classification testing.

93. The material had a natural water content of 188.5 percent and a specific gravity of 2.57. The Atterberg Limits were run on the sediment. This material was found to have a liquid limit (LL) of 105 and a plastic limit (PL) of 36; this resulted in a plasticity index (PI = LL - PL) of 69. In order to determine the grain-size distribution of the sediment, both a sieve analysis and a hydrometer analysis were performed. The grain-size distribution for this material is shown in Figure 18. By using the results of the previously mentioned tests, the composite sediment was classified according to the Unified Soil Classification System (USCS) as a black plastic



LL 105	PL 36	PI 69	GS 2.57	NAT W.% 188.5

CLASSIFICATION

PLASTIC CLAY (CH), BLACK: WITH SAND

GRADATION CURVE

PROJECT NY/NJ HARBOR SEDIMENT

BORING NO. 5-GAL-B SAMPLE NO. 0

DEPTH/ELEV 0 DATE 06 FEB 86

Figure 18. Physical classification test results for the composite bulk sediment sample

clay (CH) with sand. The designation "CH" indicates that the material is a highly plastic clay. This classification is indicative of a (composite) material composed mainly of clay particles, but which ranges in grain size from fine clay to sand.

Sedimentation Testing

94. A portion of the homogenized bulk sediment sample was used to perform sedimentation tests. The tests were performed in 8-in.-diam settling columns, in general accordance with the procedures described in TR DS-78-10 (Palermo, Montgomery, and Poindexter 1978) and Engineer Manual 1110-2-5027 (USACE 1987). Three types of sedimentation tests were performed: a series of zone settling tests, a compression settling test, and a supernatant flocculent settling test. In all of these tests, the bulk sediment was diluted to a working concentration using make-up water of 19-ppt salinity. Water samples were taken in the New York/New Jersey harbor area at locations chosen to be representative of the make-up water that will be used to reslurry dredged sediments when they are pumped out of barges. The water samples had salinities ranging from 26.5 to 32.5 ppt. However, the interstitial water from the bulk sediment sample had a salinity of 19 ppt. Using make-up water of the same salinity as the sediment interstitial water simplified accurate calculation of the diluted sediment concentration. The procedure is acceptable because settling properties do not change with increasing salinity at such high salinities. It is therefore reasonable to perform the settling test using a salinity of 19 ppt and to apply the test results to a situation where the salinity is 26.5 ppt or more.

Zone settling tests

95. A series of zone settling tests were performed at total solids concentrations ranging from 52.6 g/ℓ to 167.8 g/ℓ. In these tests, a target total solids concentration was chosen for each test. Appropriate volumes of sediment and make-up water were mixed in a drum, and the resulting sediment slurry was pumped into the settling column through a valve at the base of the column. Initially, compressed air was then bubbled up through the column through a porous disk in the column baseplate. The purpose of this procedure was to ensure that the column material was evenly mixed, because some settling could occur while the slurry was being pumped into the column. However, the

air bubbling caused a problem with an oily froth that overflowed from the top of the column, and small air bubbles were observed to remain distributed throughout the sediment for hours after the compressed air bubbling was stopped. These trapped bubbles appeared to affect the test results; therefore, the tests were rerun using new sediment with no compressed air bubbling.

96. As soon as the column had been filled, samples were taken through ports at 1-ft intervals down the column. These samples were used to determine the initial solids concentration of the test slurry in the column. An interface formed between settled solids in the lower zone and turbid supernatant in the upper zone. The height of this interface was monitored as a function of time, and a zone settling velocity was determined. The zone settling velocities (V_s) are shown in Table 16 and Figure 19 as a function of initial total solids concentration (C). It can be seen that, in general, zone settling velocity decreases with increasing initial concentration. However, at concentrations above 152 g/ℓ, it was observed that the measured velocity started to increase with increasing concentration. This effect has been observed with other test sediments. It is thought that this effect results from wall effects in the settling column and that the true settling velocities in a containment area would continue to decrease as initial concentration increased. For this reason, the two anomalous data points have been excluded from the engineering analysis.

Compression settling test

97. The compression settling test is, in effect, a zone settling test that is allowed to continue for 15 days. The column is set up as described above, and the height of the interface is monitored for 15 days. After the first few hours of zone settling, there is a transition period, and the settled solids then exhibit compression settling. In compression settling, the settling velocity of the interface decreases as time passes. The results of this test are shown in Table 17 and Figure 20. The expected influent concentration to the containment area is approximately 150 g/ℓ. However, the compression settling test was performed at a concentration of 137 g/ℓ. This reduced concentration was used to avoid the possibility of wall effects interfering with the test results. As described above, wall effects were observed at an initial concentration of just over 150 g/ℓ.

Table 16

Zone Settling Velocities as Function of

Initial Total Solids Concentration

Initial Concentration		
g/ℓ	lb/ft^3	Zone Settling Velocity (V_s), ft/hr
52.6	3.28	0.451
53.4	3.33	0.429
64.5	4.02	0.355
80.7	5.03	0.280
89.4	5.57	0.235
104.9	6.53	0.179
120.3	7.49	0.123
122.3	7.62	0.108
137.2	8.55	0.0861
151.2	9.42	0.0622
152.8	9.52	0.101*
167.8	10.45	0.199*

* These velocities are not thought to be representative of the settling characteristics of this material in a large containment area.

Flocculent settling test

98. A supernatant flocculent settling test was run concurrently with the 15-day settling test. At various times after the initiation of the test, supernatant samples were withdrawn from all the sampling ports above the settled solids interface. These samples were analyzed for total suspended solids (TSS) and turbidity (NTU). These test results allow containment area effluent quality to be estimated as a function of detention time and withdrawal depth. The test results are shown in Table 18 and Figure 21. The test was discontinued after 168 hr because iron oxides had begun to precipitate out of the supernatant water. The TSS and NTU values measured at 168 hr were slightly higher than the 96-hr values because of the iron oxide precipitate.

Consolidation Testing

99. Determination of containment area long-term storage capacity requires estimates of settlement resulting from self-weight consolidation of the newly placed dredged material. Samples of the sediments to be dredged should be tested using the finite strain (large strain) consolidation test

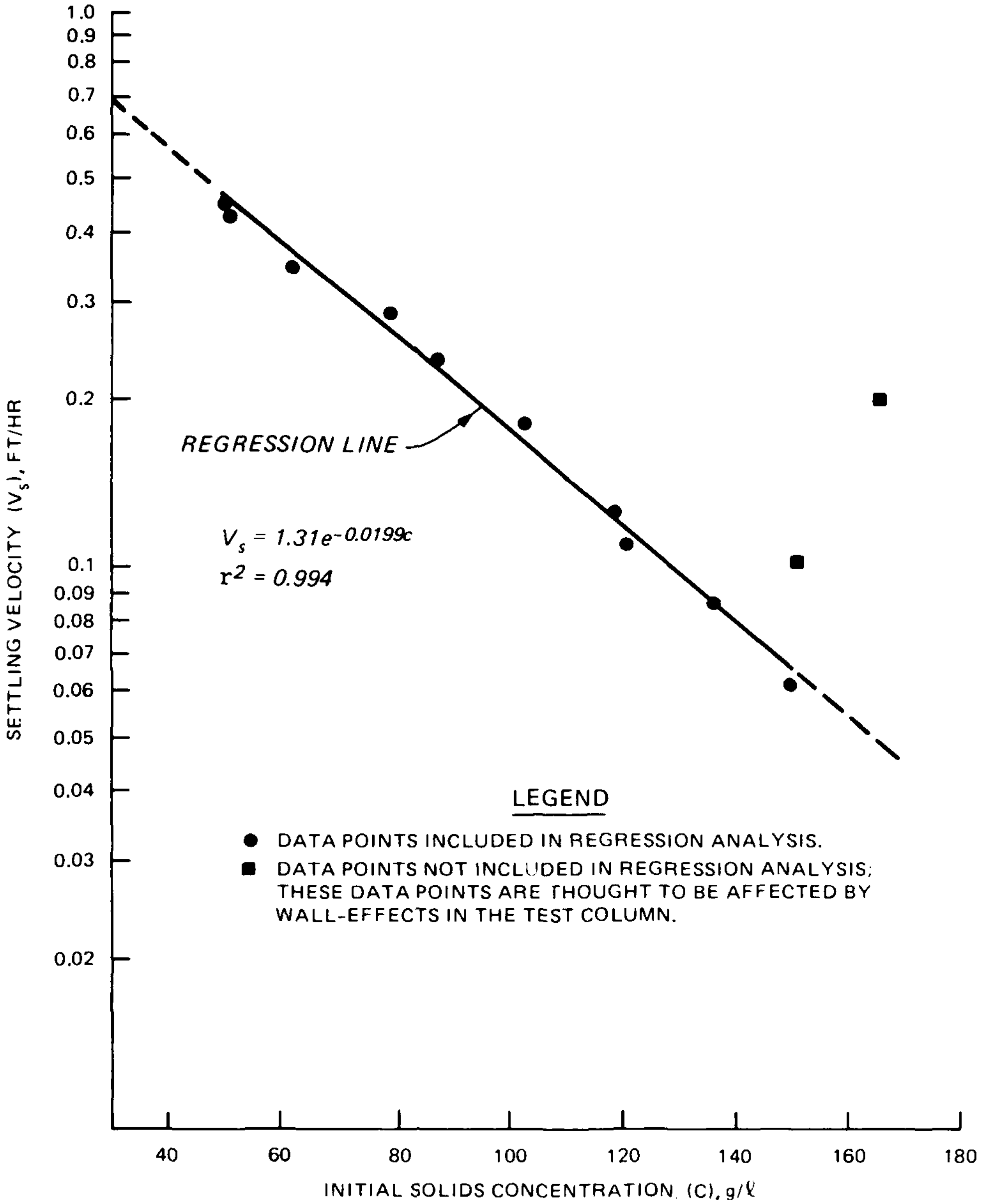


Figure 19. Results of zone settling velocity tests

procedures (Cargill 1985). These procedures require that two companion tests be run to define the void ratio-effective stress (e-σ) and the void ratio-permeability (e-k) relationships for the dredged material over the full range of anticipated void ratios. An LSCRS test provides a major portion of the required data. The self-weight consolidation test provides supplemental data at high void ratios. For both tests, only fine-grained material (passing the No. 40 sieve) should be used. The slurry used in this testing should have a

Table 17

Results of Compression Settling Test

Time, hr	Interface Height, ft	Average Settled Solids Concentration g/ℓ	Average Settled Solids Concentration lb/ft^3
0.0	5.935	137	8.53
1.0	5.710	142	8.87
2.0	5.528	147	9.16
3.0	5.380	151	9.42
4.0	5.235	155	9.68
5.0	5.073	160	9.98
6.0	4.895	166	10.35
7.0	4.715	172	10.74
8.0	4.535	179	11.17
9.0	4.365	186	11.60
10.0	4.255	191	11.90
11.0	4.170	195	12.15
12.0	4.110	198	12.32
13.0	4.050	201	12.51
14.0	4.012	203	12.63
15.0	3.975	205	12.74
16.0	3.945	206	12.84
24.0	3.740	217	13.54
28.0	3.682	221	13.76
32.5	3.628	224	13.96
46.5	3.470	234	14.60
55.0	3.400	239	14.90
73.5	3.282	248	15.43
96.0	3.169	257	15.98
129.5	3.042	267	16.65
145.5	2.997	271	16.90
168.0	2.932	277	17.28
194.0	2.878	283	17.60

(Continued)

Table 17 (Concluded)

Time, hr	Interface Height, ft	Average Settled Solids Concentration g/ℓ	Average Settled Solids Concentration lb/ft^3
216.0	2.823	288	17.94
241.0	2.775	293	18.25
264.0	2.730	298	18.55
336.0	2.630	309	19.26
360.0	2.597	313	19.50

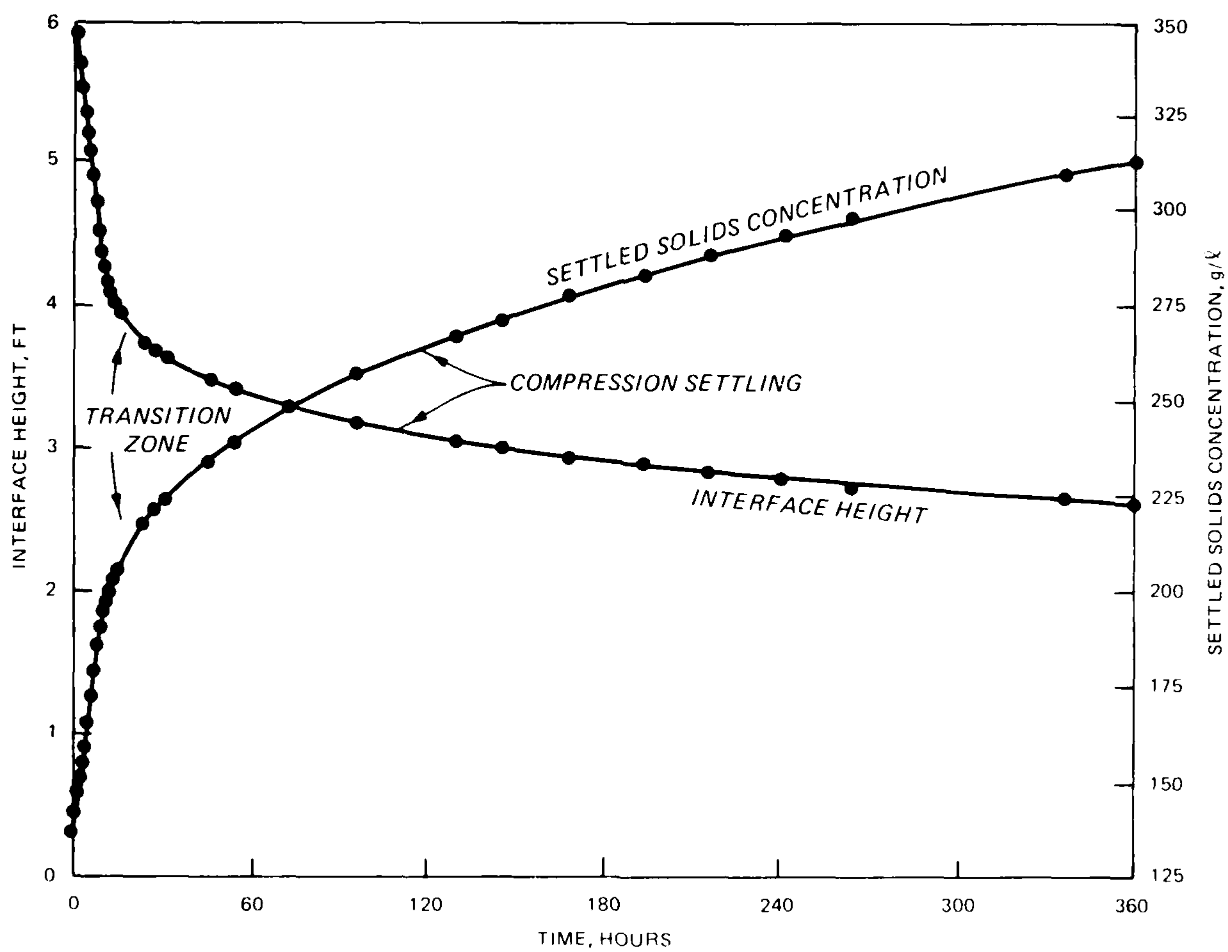


Figure 20. Compression settling test results

Table 18

Supernatant Flocculent Settling Test Results

Time, hr	Depth, ft	TSS, mg/ℓ	Turbidity, NTU
1.25	0.174	705	325
2.00	0.174	319	165
4.00	1.167	189	112
7.00	0.161	168	90
7.00	0.661	289	145
13.00	0.150	115	67
13.00	0.650	154	80
13.00	1.150	198	105
13.00	1.650	344	165
24.00	0.134	95	68
24.00	0.634	108	75
24.00	1.134	141	110
24.00	1.634	137	115
24.00	2.134	135	120
48.00	0.320	80	39
48.00	0.820	80	39
48.00	1.320	82	42
48.00	1.820	75	45
48.00	2.320	78	61
96.00	0.257	31	34
96.00	0.757	27	35
96.00	1.257	37	42
96.00	1.757	36	37
96.00	2.257	56	86
168.00	0.182	33	40
168.00	0.682	37	41
168.00	1.182	37	41
168.00	1.682	45	40
168.00	2.182	41	73
168.00	2.682	58	90

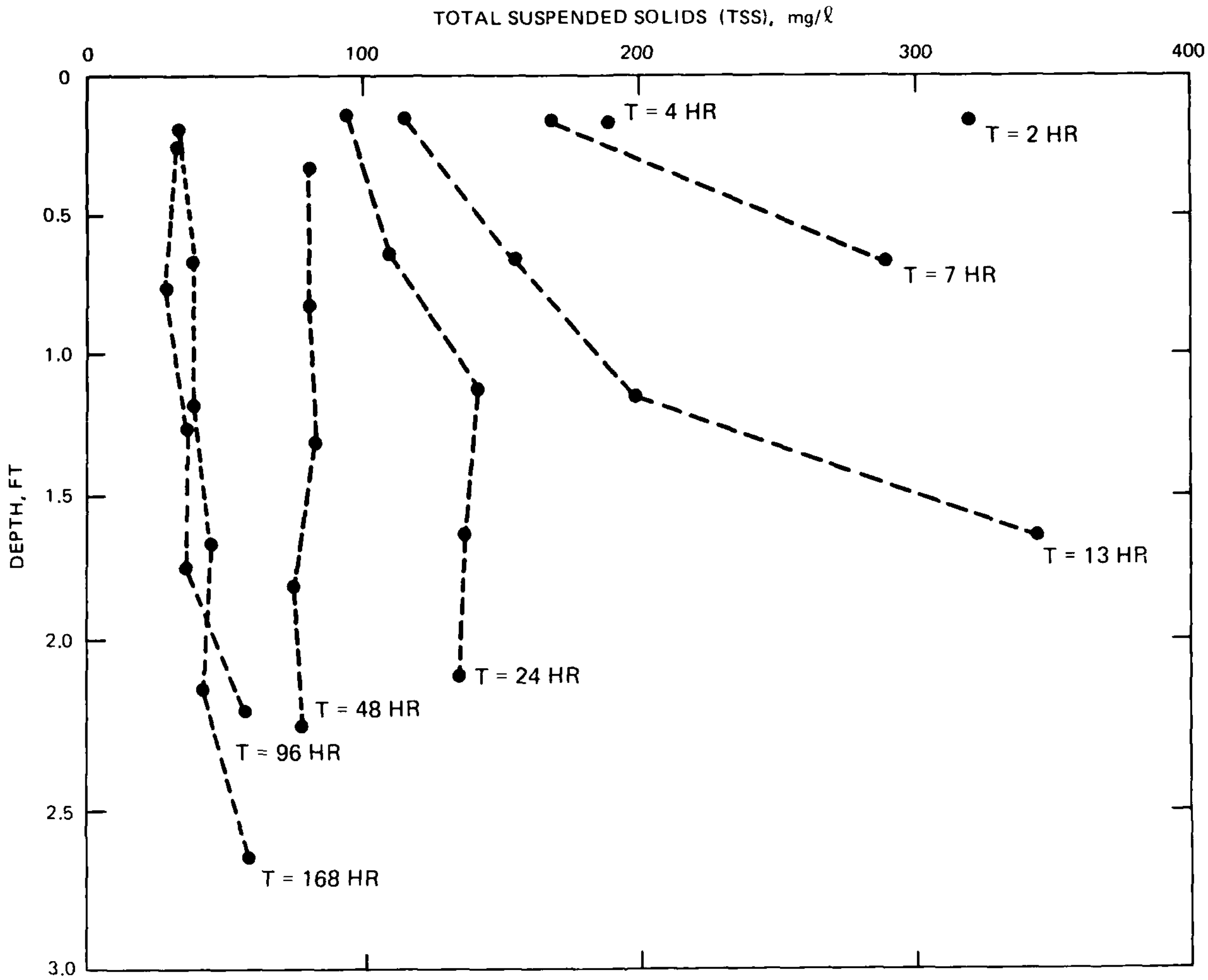


Figure 21. Supernatant flocculent settling test results

void ratio representative of the dredged material slurry as it enters the containment area.

100. A representative portion of the bulk sediment sample was obtained from one of the 55-gal drums of composited material. A portion of this sample was subjected to a self-weight consolidation test, and another portion was used for the LSCRS test. Both of these tests were conducted under contract at the US Military Academy for the WES Geotechnical Laboratory.

Self-weight consolidation test

101. The self-weight consolidation device consists of a Plexiglas cylinder that allows consolidation testing and subsequent incremental sampling of a specimen 6 in. in diameter and 9 in. high. Dredged material slurry at a void rate of 10.3 was placed in the consolidometer and was allowed to undergo

self-weight consolidation. Deformation-versus-time data were collected during the consolidation process. After completion of primary consolidation, the test device was disassembled, and the specimen was sampled in half-inch increments to obtain the necessary data to calculate void ratio, effective stress, and permeability values for the upper portion of the $e-\sigma$ and $e-k$ curves. Void ratios encountered in the specimen after completion of this test ranged from 8.6 at the top to 5.0 at the bottom of the specimen, as shown in Figure 22.

LSCRS consolidation test

102. The LSCRS test involves deformation of a large cylindrical specimen of slurry under a controlled, but variable, rate of strain. The sediment was mixed to a void ratio of 9.49 and was placed in the LSCRS test device. The specimen tested was 6 in. in diameter and 9 in. in height. During the test, measurements were made of the effective stress at each end of the specimen, and the excess pore water pressure was measured throughout the sample height. With these measurements, the required consolidation properties were calculated for the lower end of the range of void ratios encountered in a dredged material containment area. These data were combined with results of the self-weight test. The resulting compressibility data (the void ratio-effective stress relationship) are plotted in Figure 23. Permeability characteristics of the sediment tested are shown in Figure 24.

Modified Elutriate Testing

103. A modified elutriate analysis was performed on the sediment samples that had been collected and stored in glass jars. This test is designed to simulate the release of chemical contaminants to the supernatant water in a containment area. The procedures used in the test were generally in accordance with those described in the Environmental Effects of Dredging Technical Notes EEDP-04-1 (Environmental Lab (EL) 1985a) and EEDP-04-2 (EL 1985b). A bulk sediment analysis was also performed to define the initial contaminant concentrations in the homogenized sediment sample.

104. The sediment samples were homogenized into a single mixture, as described in Part III, and a sample of the sediment mixture was analyzed for bulk contaminant chemical concentrations. The results of this bulk sediment chemistry analysis are presented in Appendix A. The water samples were a so

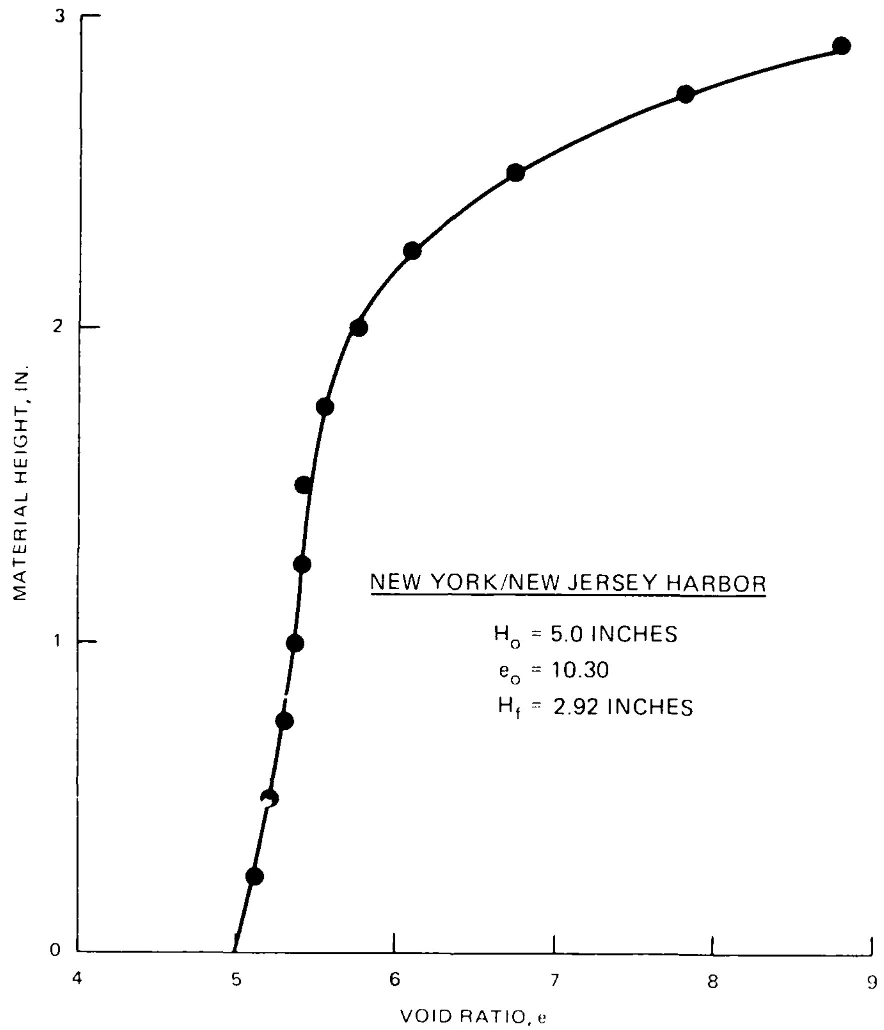


Figure 22. Void ratio distribution in the self-weight consolidation test

mixed to form a single water sample, and a portion was taken for chemical analysis. The results of the background water chemistry test are given in Appendix B.

105. Appropriate volumes of sediment and water were mixed to form a slurry with an initial total solids concentration of 150 g/ℓ. The slurry was poured into two 2-ℓ glass cylinders. Glass tubing was connected to the laboratory compressed air supply and then inserted to the bottom of the glass cylinders. The airflow was adjusted so that it agitated the slurry vigorously

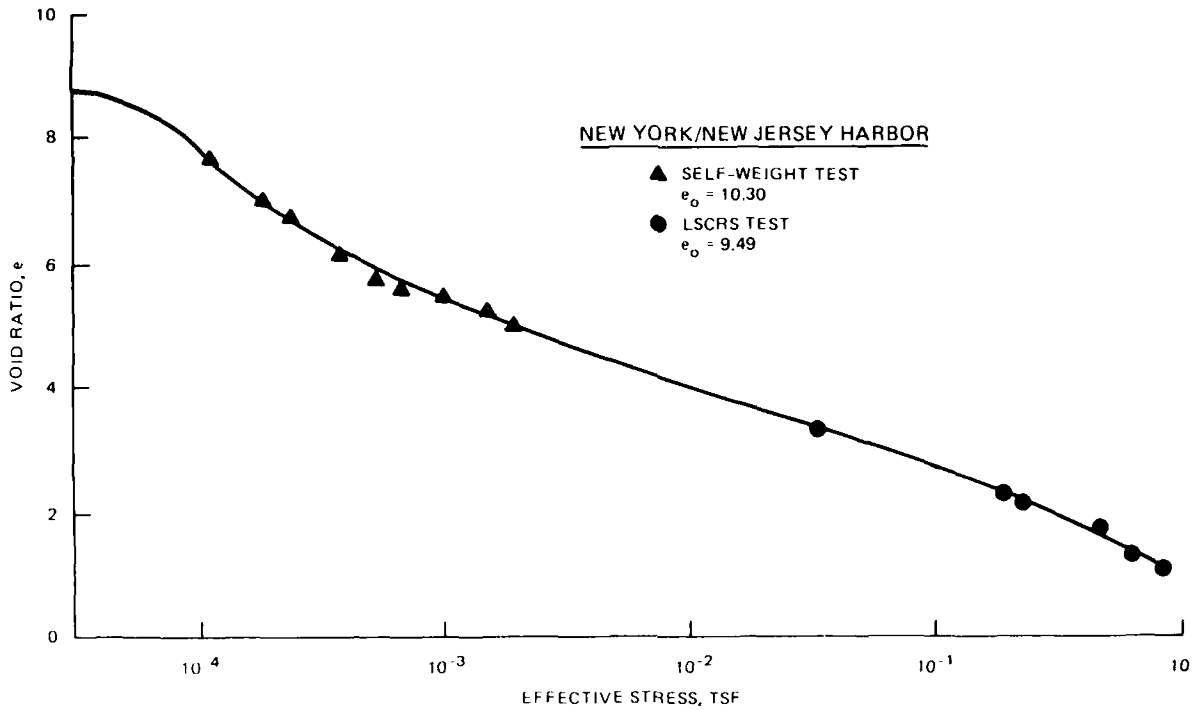


Figure 23. Void ratio-effective stress relationship for the New York/New Jersey Harbor sediment

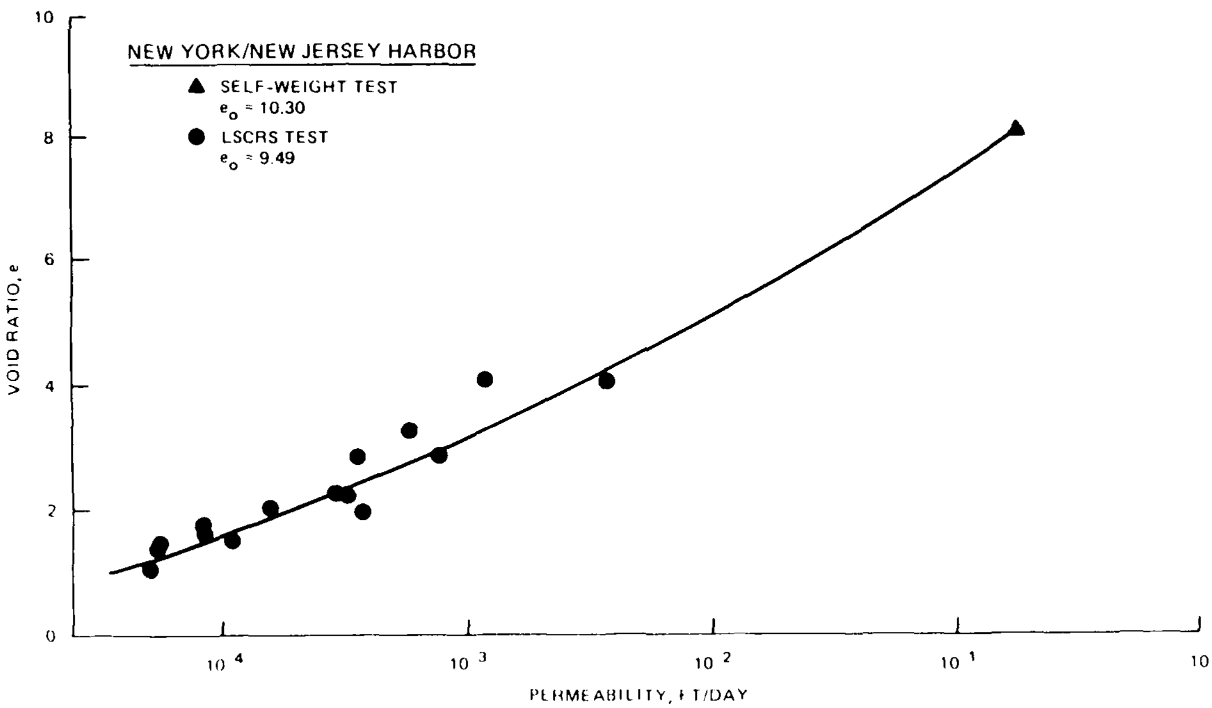


Figure 24. Voir ratio-permeability relationship for the New York/New Jersey Harbor sediment

for 1 hr. After bubbling air through the slurry for 1 hr, the glass tubing was removed, and the slurry was allowed to settle for 24 hr under quiescent conditions. During the settling period, an interface formed between a lower zone of settled solids and an upper zone of relatively clear supernatant. After the 24-hr settling period, the supernatant water was removed by pipette and set aside for analysis.

106. Because of the number of elutriate parameters requested by the USAED, New York, the volume of supernatant from the modified elutriate test appeared inadequate for the number of analyses to be performed. It was therefore necessary to extract additional water from the settled solids. The settled solids were therefore transferred into centrifuge jars and centrifuged at approximately 1,400 g's for 2 hr. The water extracted from the settled solids was filtered through glass fiber filters having a pore size of approximately 1 μ. It was then analyzed for dissolved contaminant concentrations. The glass fiber filters were used because analyses were to be performed for pesticides and polychlorinated biphenyls (PCBs), and these compounds tend to adsorb to plastic filter materials. This procedure is a deviation from the published modified elutriate procedure. However, it is thought that the dissolved contaminant concentrations in the extracted water were probably very similar to those in the supernatant. The test yields a conservative estimate of dissolved contaminant concentrations, because the longer sediment/water contact time allows some increase in dissolved contaminant concentration for any contaminant that has not already reached equilibrium during the initial stirring process. The dissolved contaminant concentrations from the filtered modified elutriate test are shown in Appendix C.

107. The supernatant water from the modified elutriate test was left unfiltered and was analyzed for total contaminant concentrations. These results are shown in Appendix D. For a few contaminants (cadmium, copper, nickel, zinc, barium), the total contaminant concentration from the unfiltered modified elutriate test is lower than the dissolved concentration from the filtered test. However, with the possible exception of barium, the differences in concentration are not statistically significant and can be attributed to random errors caused by the limits of analytical accuracy.

PART VI: CONTAINMENT AREA FILLING SIMULATIONS

General Site Conditions

108. The disposal site characteristics and general conditions described in Part II were used in conjunction with the consolidation characteristics of the sediment (described in Part V) to develop filling simulations for each of the CDFs.

109. The physical characteristics of the CDFs were previously shown in Table 4. Pertinent consolidation characteristics of both the foundation soil and dredged material are listed in Table 19.

110. As discussed in Part II, the entire 0.68 M cu yd of contaminated material will be placed in the 500-acre containment island if that disposal option is used. Alternatively, the 0.68 M cu yd of sediment will be divided equally among the four nearshore sites, resulting in placement of approximately 169,000 cu yd annually into each of these CDFs.

111. For the four-site disposal alternative, the storage life of the individual sites was different because of differences in CDF physical dimensions and dredged material lift thicknesses. During the filling simulations, it was assumed that as the smaller sites were filled, their remaining disposal volume was deposited in the largest site, the Raritan Bay CDF. Any material remaining after the Raritan Bay CDF was filled was deposited in the Newark Bay facility.

Site Capacity Model

112. The consolidation and desiccation of dredged material within the containment area were simulated using the computer model entitled Primary Consolidation and Desiccation of Dredged Fill (PCDDF). The development and verification of PCDDF were presented in an earlier report by Cargill (1985). The consolidation process is modeled through the finite strain theory of consolidation, which accounts for the large deformations and nonlinear soil properties inherent in the very soft materials commonly found in maintenance dredging. The desiccation process was modeled in terms of an empirical description of the water balance in the uppermost crust in the dredged material. The increased consolidation of underlying layers as a result of the

Table 19

Consolidation Characteristics of the Foundation

Soil and Dredged Material

Foundation*			Dredged Material		
Void Ratio	Effective Stress psf	Permeability ft/day	Void Ratio	Effective Stress psf	Permeability ft/day
4.00	0.00	5.47E-03	8.75	0.00	2.60E-01
3.90	0.50	5.04E-03	8.50	0.09	2.20E-01
3.85	1.10	4.82E-03	8.25	0.12	1.90E-01
3.80	1.90	4.68E-03	8.00	0.16	1.55E-01
3.70	4.00	4.32E-03	7.75	0.20	1.25E-01
3.60	8.20	3.96E-03	7.50	0.23	1.05E-01
3.50	13.20	3.67E-03	7.25	0.28	8.50E-02
3.40	19.80	3.34E-03	7.00	0.35	6.80E-02
3.30	28.00	3.05E-03	6.75	0.44	5.40E-02
3.20	37.40	2.81E-03	6.50	0.58	4.20E-02
3.10	50.00	2.56E-03	6.00	1.00	2.50E-02
3.00	64.00	2.33E-03	5.50	1.76	1.45E-02
2.90	84.00	2.13E-03	5.00	3.60	8.20E-03
2.80	110.00	1.92E-03	4.50	8.00	4.60E-03
2.70	140.00	1.73E-03	4.00	18.00	2.60E-03
2.60	182.00	1.54E-03	3.50	44.00	1.40E-03
2.50	240.00	1.38E-03	3.00	119.00	7.50E-03
2.40	316.00	1.21E-03	2.50	208.00	3.70E-04
2.30	400.00	1.05E-03	2.00	580.00	1.80E-04
2.20	460.00	9.07E-04	1.50	1,120.00	8.00E-05
2.10	700.00	7.78E-04	1.00	2,000.00	3.40E-05
2.00	880.00	6.62E-04			
1.90	1,140.00	5.40E-04			
1.80	1,480.00	4.42E-04			
1.70	1,900.00	3.53E-04			
1.60	2,460.00	2.84E-04			
1.50	3,200.00	2.23E-04			
1.40	4,160.00	1.73E-04			
1.30	5,400.00	1.34E-04			
1.20	7,000.00	1.02E-04			
1.10	9,000.00	7.63E-05			
1.00	11,400.00	5.90E-05			

* The specific gravity of the foundation soil was assumed to be 2.70.

surcharge due to this crust is also included. PCDDF uses an explicit finite difference scheme for modeling the one-dimensional consolidation process and makes monthly adjustments in the top boundary condition and boundary location in accordance with the amount of desiccation that has occurred. In addition to material settlement that comes from a calculation of the void ratio distribution, the program also calculates the distribution of stresses and pore pressures through the layer, which is indicative of soil strength. Any sequence of material deposition as well as consolidation in an underlying foundation can be considered. The model is currently limited to the deposition of material with similar consolidation properties; i.e., deposits of material with dissimilar consolidation characteristics cannot be modeled. The accuracy of PCDDF to simulate the settlement resulting from consolidation and desiccation has been verified for a number of sites (Cargill 1985).

113. Two scenarios of dewatering activities were simulated to give a range of probable desiccation rates. One case restricted all desiccation, whereas the other scenario evaluated the influence of efficient surface drainage and maximum drying conditions. Desiccation parameters required for PCDDF were evaluated from the physical properties of the dredged material and are presented in Table 20.

Results of Simulations

114. The primary objective of the simulation task was to determine the useful life of the alternative disposal sites, defined as the period in which the surface elevation in the site is below the dike crest, allowing for freeboard requirements. In the four-site disposal case, as the individual facilities filled, the remaining material was distributed into the Raritan Bay and Newark Bay CDFs. The filling sequence for this disposal scenario is presented in Table 21.

115. Time series of the surface elevations in each of the six sites during the filling periods are presented in Figures 25 through 30 with the "a" curve indicating the filling sequence with no dewatering and the "b" curve indicating that active dewatering was considered. Table 22 summarizes the storage life estimates obtained from PCDDF simulations. The influence of dewatering activities is manifested in the difference in storage life estimates, with increases of 1 to 24 years for the various sites attributable to

Table 20

Desiccation Parameters for the Dredged Material

Parameter	Value
Surface drainage efficiency	100%
Field-to-pan coefficient	100%
Void ratio at end of first stage evaporation	5.02
Void ratio at end of drying	1.38
Saturation of dried crust	80%
Maximum thickness of crust	1.00 ft
Delay after disposal until material is exposed to evaporative drying	90 days

an active dewatering program. The increased storage life results from additional surface settlement. The increased surface settlement occurs, in part, because the upper portion of the dredged material layer dries and decreases in volume. It also occurs partly because the water table within the dredged material drops during drying; the material above the water table then exerts a greater weight, or effective stress, on underlying material than it did when it was surmerged. Comparisons of settlement amounts for active and inactive dewatering scenarios are detailed in Table 23.

116. During the execution of PCDDF, desiccation of the exposed material was prevented when the solids surface was below the mean high water (MHW) elevation of el +5 MLW. Unrealistic, long-term oscillations about the MHW were observed in the simulations of thin (less than 1.5 ft) dredged material deposits when placed on top of a thick (greater than 20 ft) layer of compressible material. This phenomenon is an artifact of the PCDDF desiccation algorithm and occurred in the active dewatering simulations of the containment island with sheetwall dikes and the upland sites for Raritan Bay and Newark Bay. The filling simulations for these sites were completed by reducing the thickness of the underlaying layer of compressible material to approximately 5 ft and superimposing the results above the MHW onto the results from the prior simulations. This procedure produced a conservative estimate of the useful life for these sites because of the lower settlement rates of the underlying material.

Table 21

Filling Sequence for the Four Upland Sites

	Active Dewatering, ft				No Dewatering, ft			
Year	Raritan Bay	Newark Bay	Bowery Bay	Flushing Bay	Raritan Bay	Newark Bay	Bowery Bay	Flushing Bay
1	0.47	1.02	2.42	2.95	0.47	1.02	2.42	2.95
2	0.47	1.02	2.42	2.95	0.47	1.02	2.42	2.95
3	0.47	1.02	2.42	2.95	0.47	1.02	2.42	2.95
4	0.47	1.02	2.42	2.95	0.47	1.02	2.42	2.95
5	0.47	1.02	2.42	2.95	0.47	1.02	2.42	2.95
6	0.47	1.02	2.42	2.95	0.47	1.02	2.42	2.95
7	0.47	1.02	2.42	2.95	0.47	1.02	2.42	2.95
8	0.47	1.02	2.42	2.95	0.47	1.02	2.42	2.95
9	0.47	1.02	2.42	2.95	0.47	1.02	2.42	2.95
10	0.47	1.02	2.42	2.95	0.95	1.02	2.42	(filled)
11	0.95	1.02	2.42	(filled)	0.95	1.02	2.42	
12	0.95	1.02	2.42		0.95	1.02	2.42	
13	0.95	1.02	2.42		0.95	1.02	2.42	
14	0.95	1.02	2.42		1.42	1.02	(filled)	
15	0.95	1.02	2.42		1.42	1.02		
16	0.95	1.02	2.42		1.42	1.02		
17	1.42	1.02	(filled)		1.42	1.02		
18	1.42	1.02			1.42	1.02		
19	1.42	1.02			1.42	1.02		
20	1.42	1.02			1.42	1.02		
21	1.42	1.02			1.42	1.02		
22	1.42	1.02			1.42	1.02		
23	1.42	1.02			(filled)	4.06		
24	1.42	1.02				(filled)		
25	1.42	1.02						
26	1.42	1.02						
27	1.42	1.02						
28	1.42	1.02						
29	1.42	1.02						
30	1.42	1.02						
31	1.42	1.02						
32	1.42	1.02						
33	1.42	1.02						
34	1.42	1.02						
35	1.42	1.02						
36	1.42	1.02						
37	1.42	1.02						
38	1.42	1.02						
39	1.42	1.02						
40	(filled)	4.06						
41		4.06						
42		(filled)						

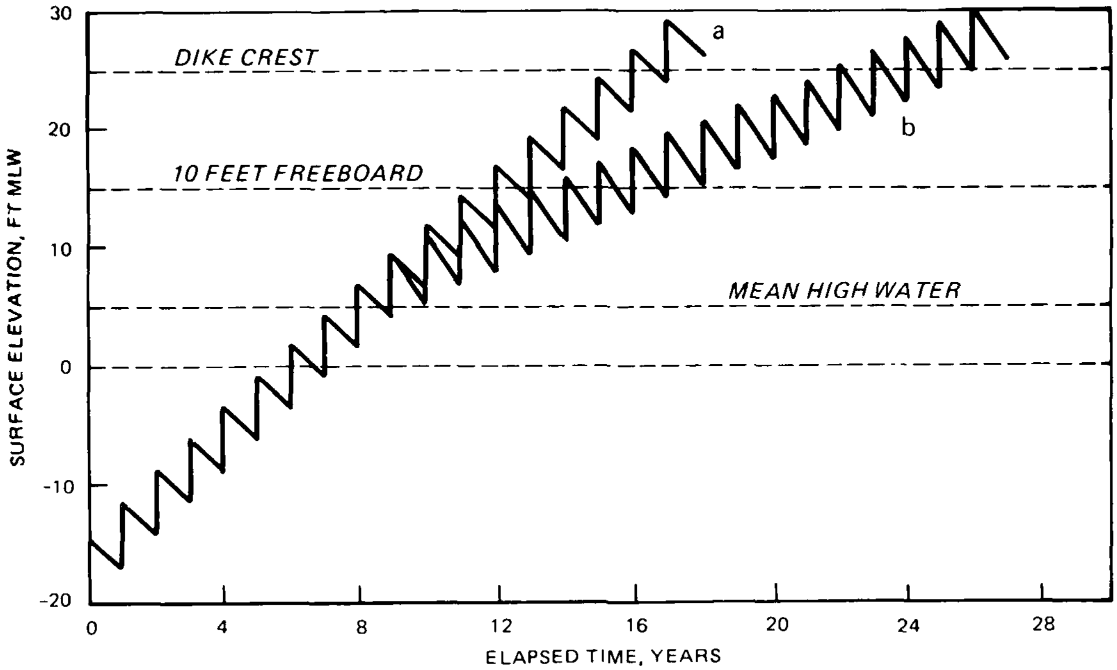


Figure 25. Filling simulation for disposal of dredged material at the New York/New Jersey containment island with sand dikes

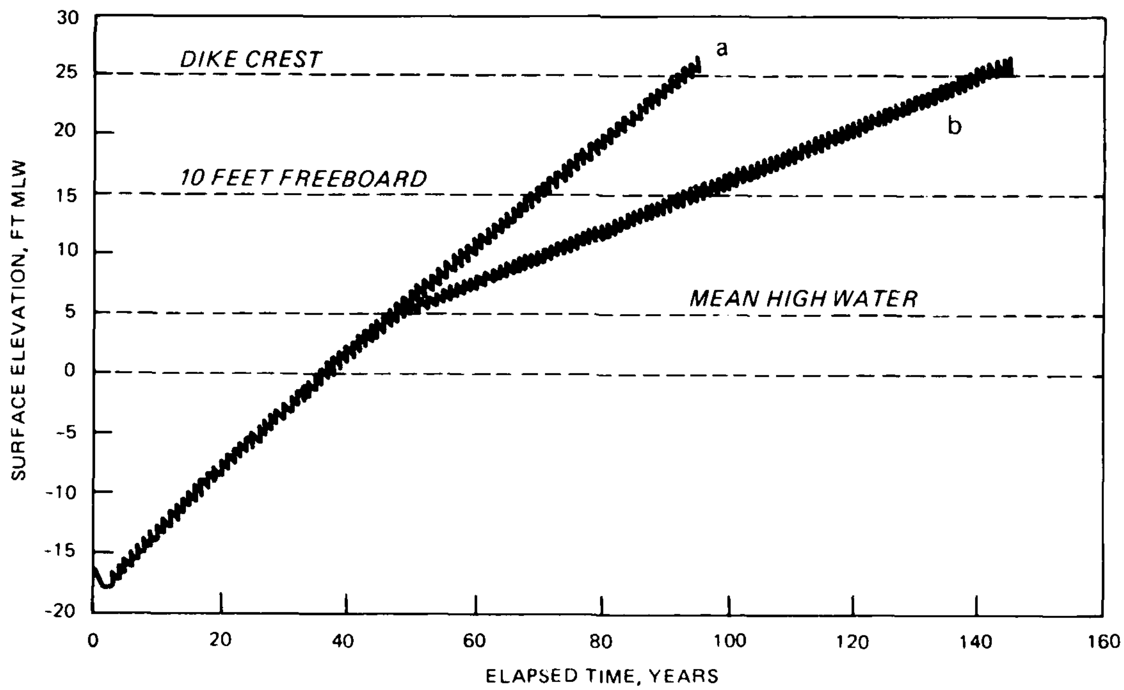


Figure 26. Filling simulation for disposal of dredged material at the New York/New Jersey containment island with cofferdam dikes

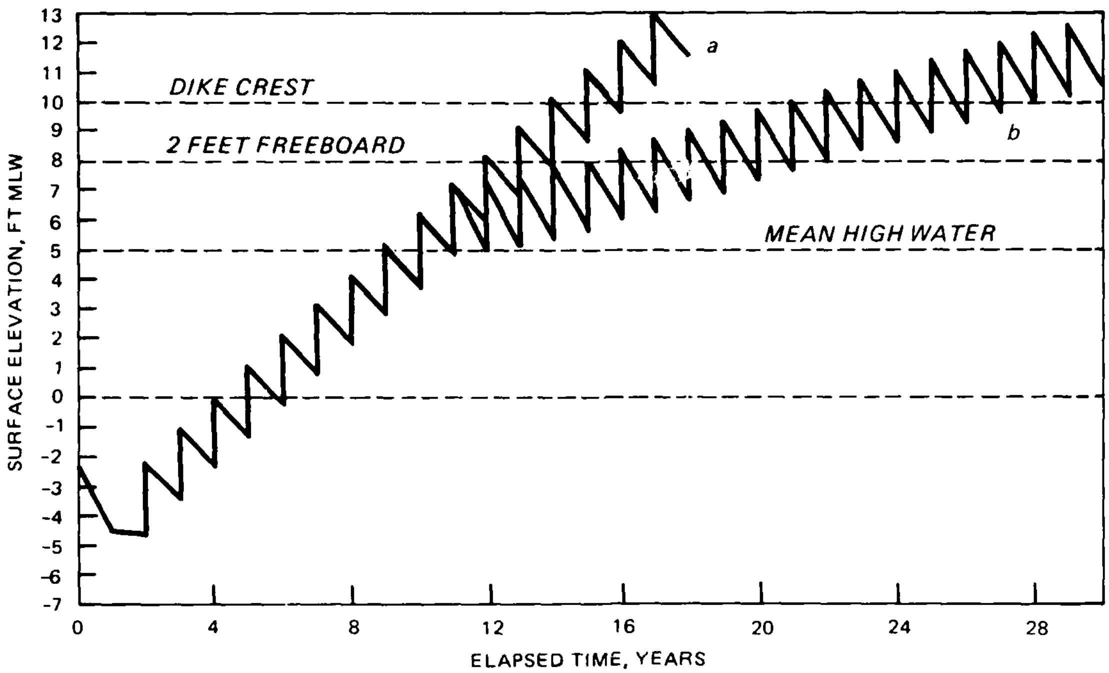


Figure 27. Filling simulation for disposal of dredged material at Bowery Bay, New York

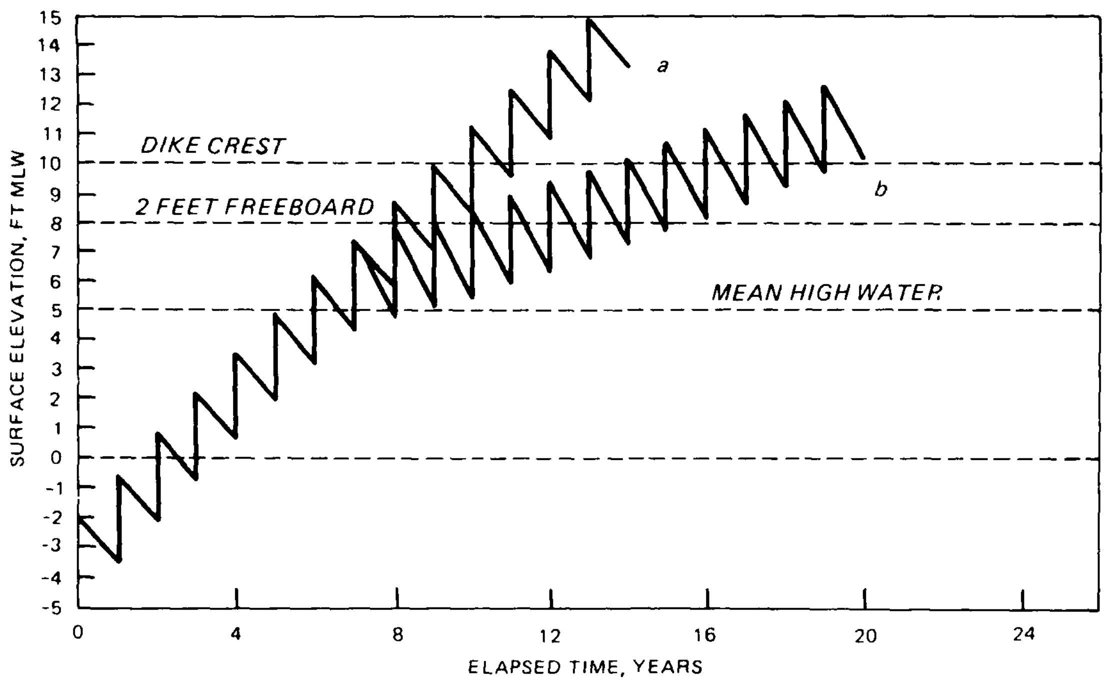


Figure 28. Filling simulation for disposal of dredged material at Flushing Bay, New York

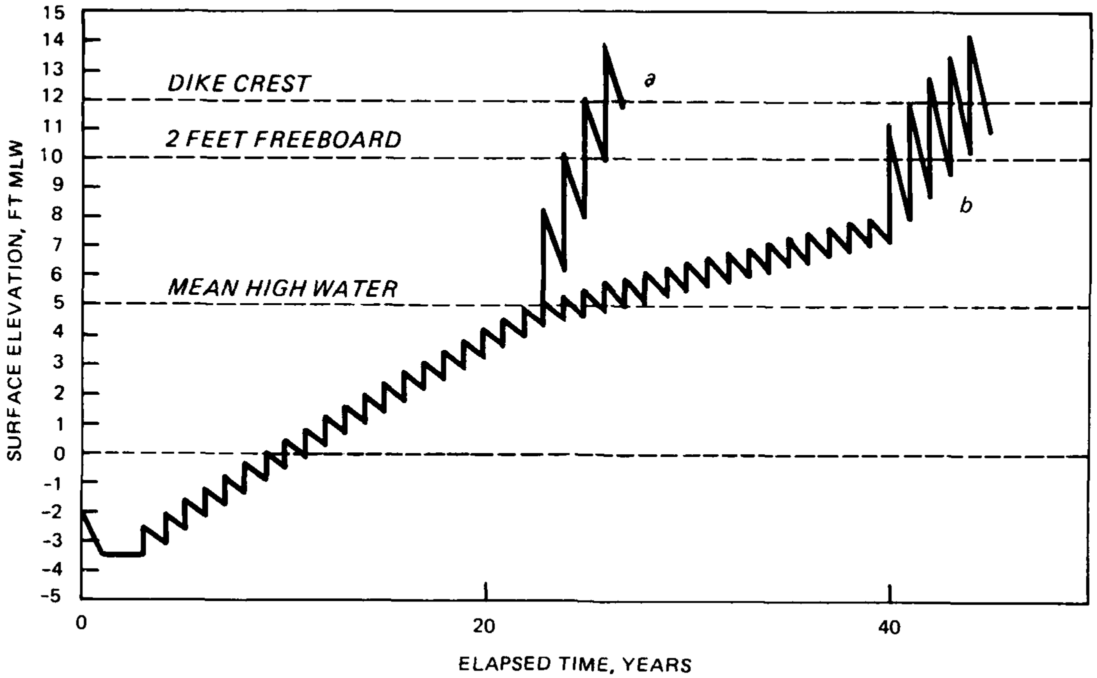


Figure 29. Filling simulation for disposal of dredged material at Newark Bay, New Jersey

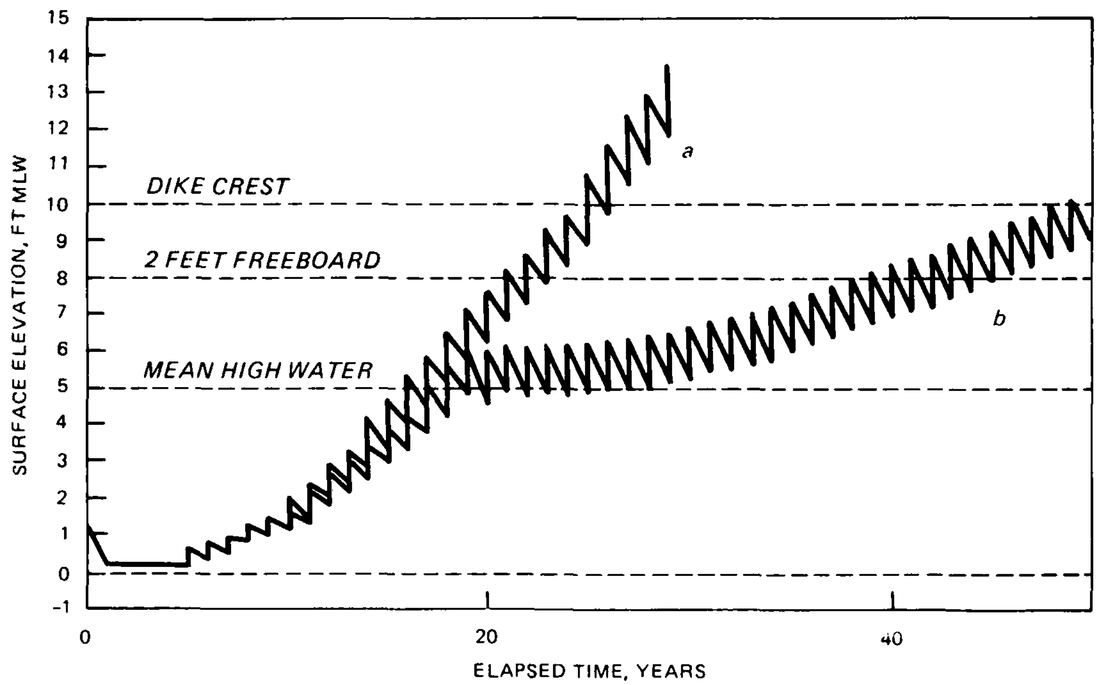


Figure 30. Filling simulation for disposal of dredged material at Raritan Bay, New Jersey

Table 22

Summary of Simulation Results

Site	Dewatering Scenario	Time To Reach MLW years	Time To Reach MHW years	Time To Reach Capacity years
Containment island	Active	7	9	15
(sand dikes)	Inactive	7	9	13
Containment island	Active	37	48	93
(cofferdam dikes)	Inactive	37	48	68
Bowery Bay	Active	6	10	16
	Inactive	6	10	13
Flushing Bay	Active	3	7	10
	Inactive	3	7	9
Newark Bay	Active	11	24	41
	Inactive	11	22	23
Raritan Bay	Active	1	18	39
	Inactive	1	17	22

Table 23

Summary of Settlement Results at End of Filling

Site	Dewatering Scenario	Settlement			
		Foundation ft	Consolidation ft	Desiccation ft	Total ft
Containment island	Active	0.0	45.51	4.02	49.53
(sand dikes)	Inactive	0.0	36.61	0.0	36.61
Containment island	Active	0.0	40.19	55.54	95.73
(cofferdam dikes)	Inactive	0.0	54.57	0.0	54.57
Bowery Bay	Active	1.51	19.89	4.38	25.78
	Inactive	1.28	16.54	0.0	17.82
Flushing Bay	Active	1.17	15.15	2.80	19.12
	Inactive	1.07	13.49	0.0	14.56
Newark Bay	Active	1.80	18.68	14.33	34.81
	Inactive	1.67	14.61	0.0	16.28
Raritan Bay	Active	3.11	18.92	11.98	34.10
	Inactive	1.18	10.28	0.0	11.46

PART VII: EFFLUENT WATER QUALITY EVALUATIONS

Total Suspended Solids in Effluents

117. The settling test data and modified elutriate test data described in Part IV were used to develop predictions of the water quality in effluents from various containment areas under consideration by the USAED, New York. The effluent quality is a function of the characteristics of the dredged material, the design of the containment area, and the characteristics of the disposal operation. Unfortunately, detailed disposal operations information such as discharge flow rates and duration of dredging is not currently available. The effluent quality predictions presented in this report are therefore based upon estimates of representative operational conditions specified by the USAED, New York.

118. The USAED, New York, advised that disposal operations would probably be similar to those used in the USAED, Norfolk, at the Craney Island CDF. It was therefore assumed that material for disposal would be brought to the disposal sites in barges, reslurried to an average concentration of approximately 150 g/ℓ, and pumped into the disposal sites at a flow rate of approximately 45 cfs. It was unlikely that a flow rate of 45 cfs would be maintained continuously for 24 hr/day in such an operation, and the number of hours per day of pumping would depend on project conditions. Consequently, effluent quality predictions have been made at a range of mean daily flow rates for each site. It should be clearly understood that if disposal operation plans change so that these assumptions about disposal operations are unrealistic, the water quality predictions should be recalculated.

119. Assumptions were also made about the designs of the proposed disposal sites. These assumptions were chosen to be consistent with those presented in Poindexter (in preparation) and Walski and Schaefer (1988), and are listed in Table 24. Again, the reliability of the effluent quality predictions depends on the validity of these assumptions.

120. The maximum acceptable flow rates for each containment area and the expected effluent suspended solids were calculated using the ADDAMS computer-aided design package developed at the WES (Hayes et al., in preparation). This computer program uses the design procedures described in Technical Report DS-78-10 (Palermo, Montgomery, and Poindexter 1978).

Table 24

Assumptions Made in Modeling Characteristics of Proposed Containment Areas

Site	Ponding Area acres	Dike Crest Height* ft	Minimum Ponding Depth ft	Freeboard ft	Resuspension Factor	Annual Quantity** of Material To Be Disposed cu yd^3
Containment island (cofferdam dikes)	500.0	45	2	10	2.0	676,000
Containment island (sand dikes)	117.0	45	2	10	2.0	676,000
Raritan Bay	335.0	11	2	2	2.0	169,000
Newark Bay	156.0	17	2	2	2.0	169,000
Bowery Bay	65.4	17	2	2	1.5	169,000
Flushing Bay	53.7	15	2	2	1.5	169,000

* Dike crest height is referred to interior base of containment area, not to MLW.

** Annual quantities of material to be disposed of into each site are given in channel yardages: an in situ void ratio of 4·84 was used based on the laboratory analyses of sediment samples. This value is not significantly different from the value of 5·0 that was assumed in Poindexter (in preparation).

Laboratory data analysis

121. For the laboratory test data described in Part V to be used, equations must be fitted to the test data. This task is performed by the Automated Dredging and Disposal Alternatives Management System (ADDAMS) design model when the raw test data are entered into the computer. The data and the fitted equations are then plotted so that the design engineer may adjust them as necessary.

122. The zone settling data are shown in Figure 31. It can be seen from the plot that all but two of the data points can be fitted very well by a straight line. The two outlying data points were felt to be the result of wall effects in the settling column, as explained in Part V. Since they were not thought to be representative of dredged material behavior in a containment area, they were excluded from the analysis. A straight line was fitted to the remaining 10 data points, yielding an R-squared value of 0.994. The equation of the regression line is given in Figure 31. This fitted regression line was used to develop the solids loading curve shown in Figure 32. In this plot, the solids loading rate was calculated by multiplying the solids concentration by the corresponding settling velocity calculated from the regression line in Figure 31.

123. The compression settling data from the 15-day test are shown in Figure 33. Again, a straight line is fitted to the data using linear regression. The equation is given in Figure 33, and it is clearly a good fit with an R-squared value of 0.996.

124. The data from the flocculent settling test are shown in Figure 34. It can be seen that the data have been transformed from simple concentrations to percentages of the supernatant concentration after 1 hr (705 mg/ℓ). It can also be seen that the same depths are used to plot data at each time interval. This happens because the ADDAMS model will allow only a limited number of sampling depths to be used. However, the maximum deviation from true sampling depth is only 0.16 ft, and the predictions of effluent quality that are based on this analysis are not significantly affected by such small changes in the input data. The data for periods later than 96 hr are not plotted because they are not significantly lower than the 96-hr concentrations. The fitted curves in Figure 34 are used to calculate the averaged effluent quality that will result at each time interval depending on the ponding depth. These calculated data points are plotted in Figure 35, and regression curves are fitted

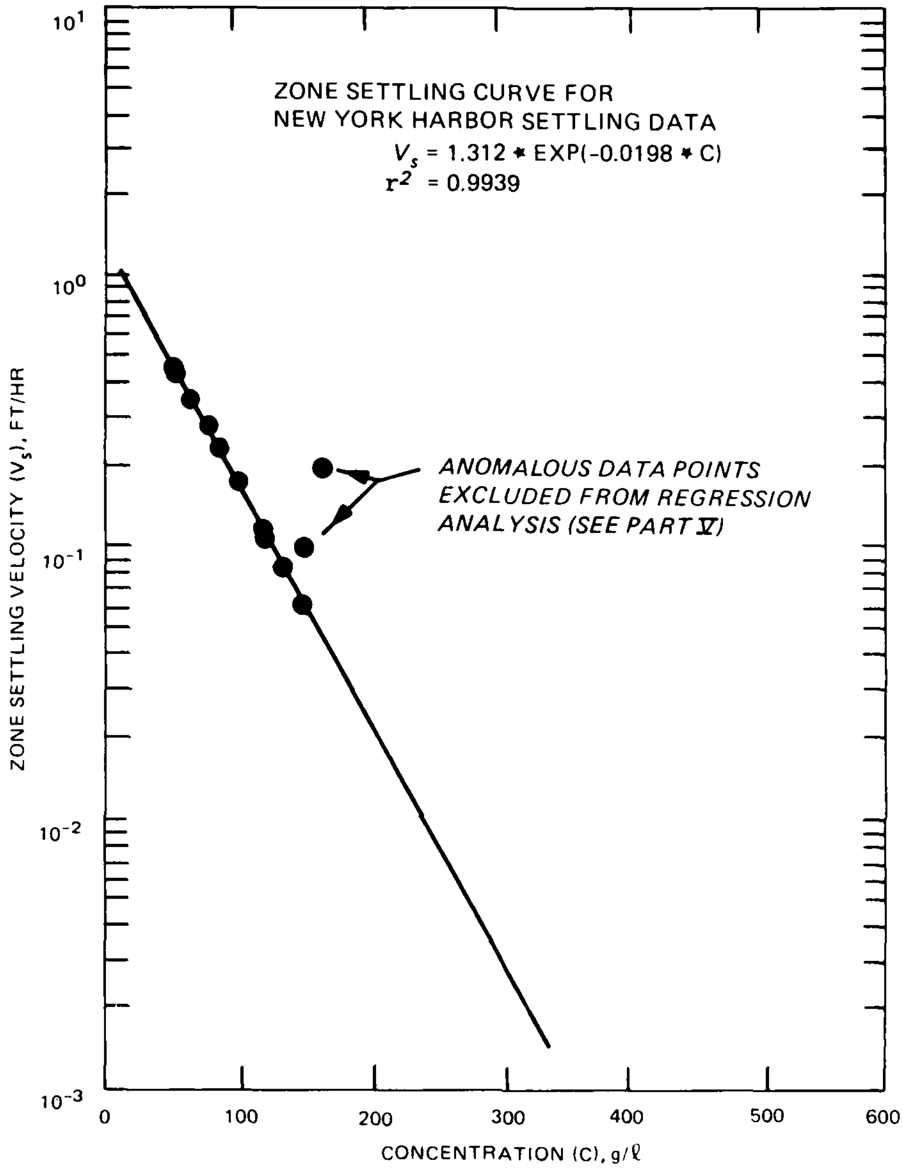


Figure 31. New York/New Jersey Harbor zone settling data

to them. These regression curves allow the effluent total suspended solids to be estimated as a function of retention time and ponding depth. It should be noted that these concentrations are given for idealized quiescent conditions. However, conditions in a containment area are rarely quiescent, and the predicted effluent concentrations are later adjusted to account for this.

Limiting flow conditions

125. Three major processes must take place in a containment area if solids removal is to be significant. Each of these processes depends on the

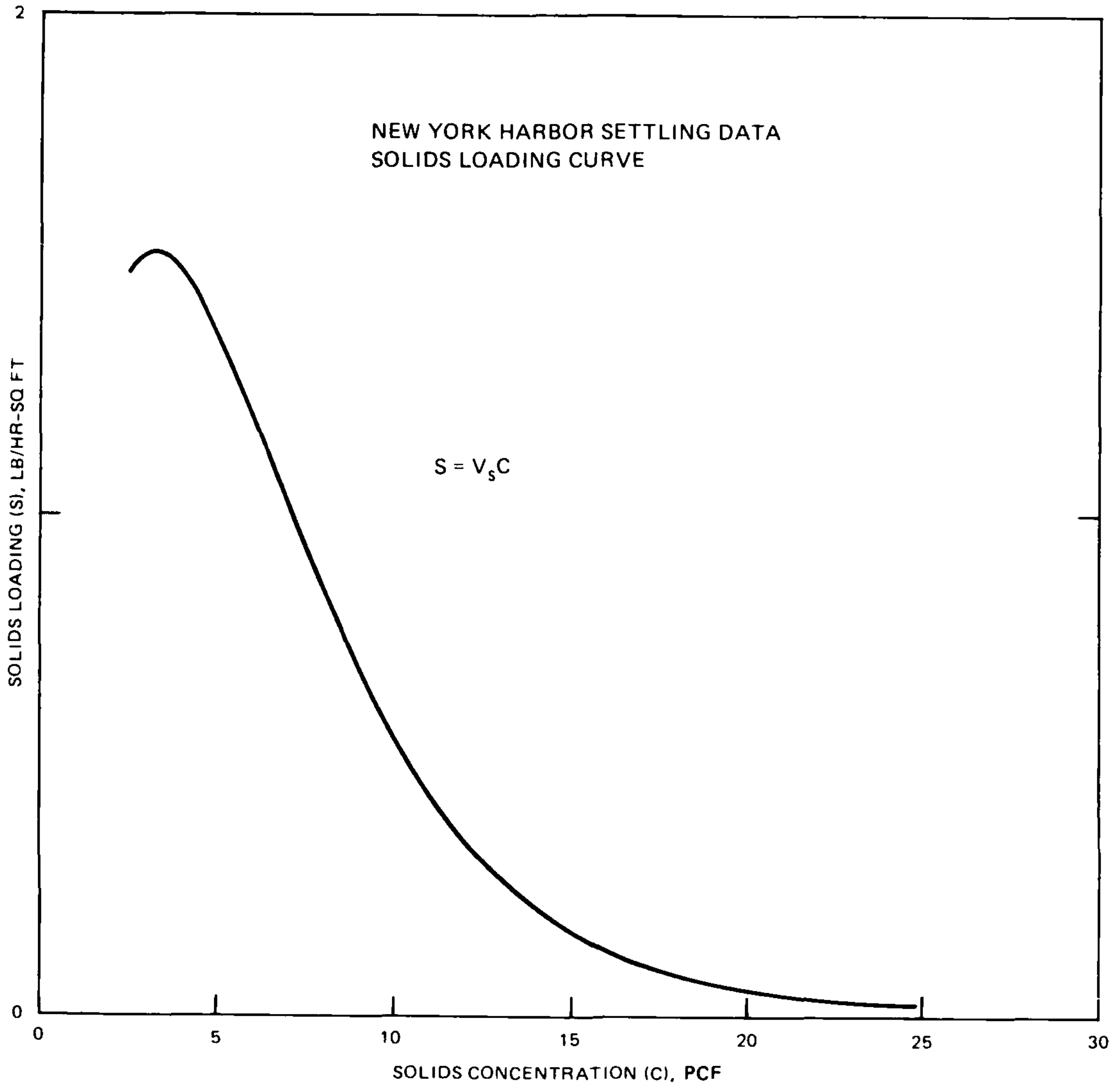


Figure 32. Solids loading curve for New York/New Jersey Harbor dredged material

dredged material, containment area, and disposal operation characteristics. Once all these characteristics are specified, it is possible to calculate a maximum inflow rate to the containment area for each process to be effective. The ADDAMS model calculates this maximum acceptable flow. The limiting flow for each containment area is the lowest of the three calculated maximum flow rates, since it is only at inflows less than this value that all three processes will be effective.

126. The first process is supernatant production. Clearly the discharge rate from the containment area cannot exceed the rate at which

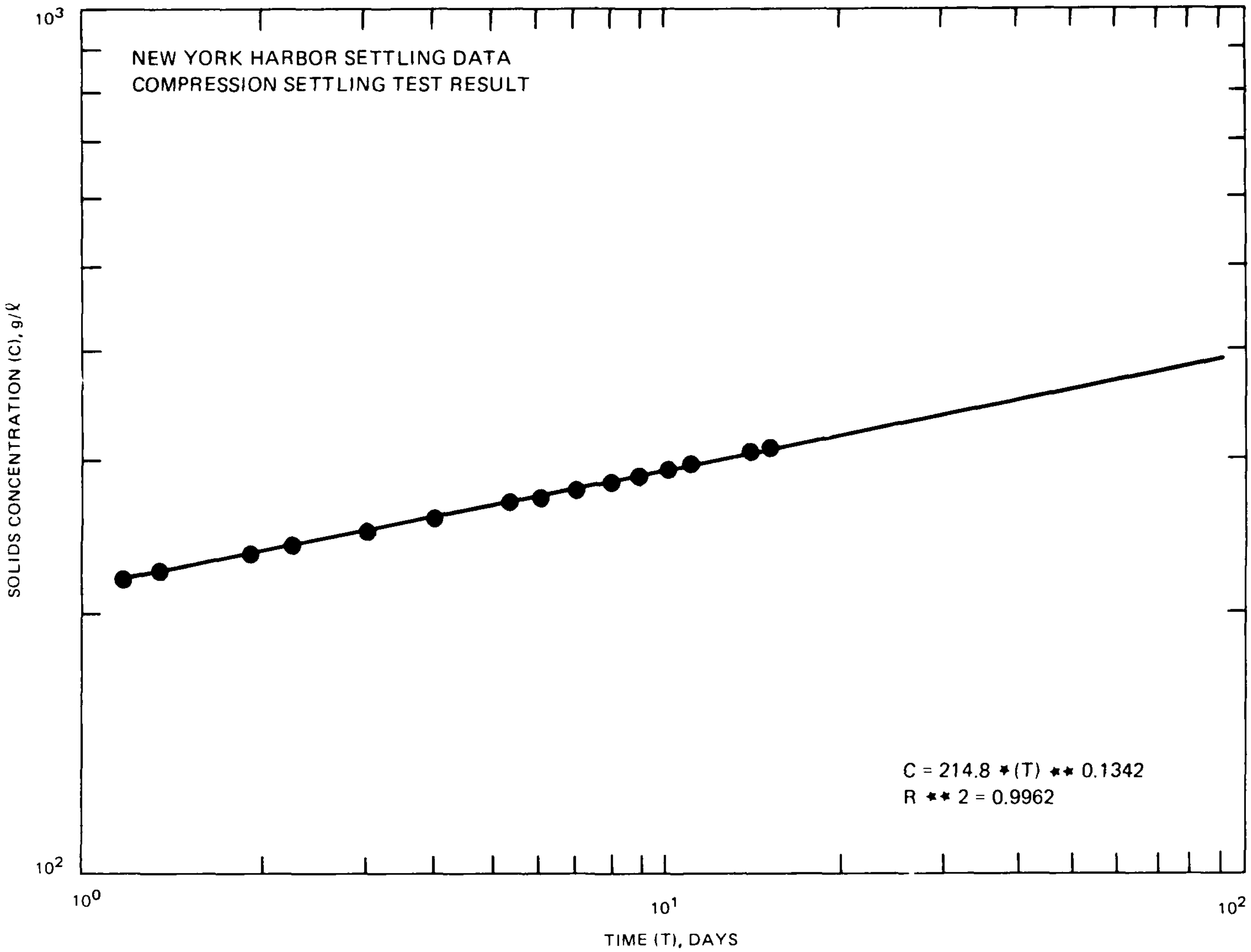


Figure 33. Compression settling data from New York/New Jersey Harbor 15-day test

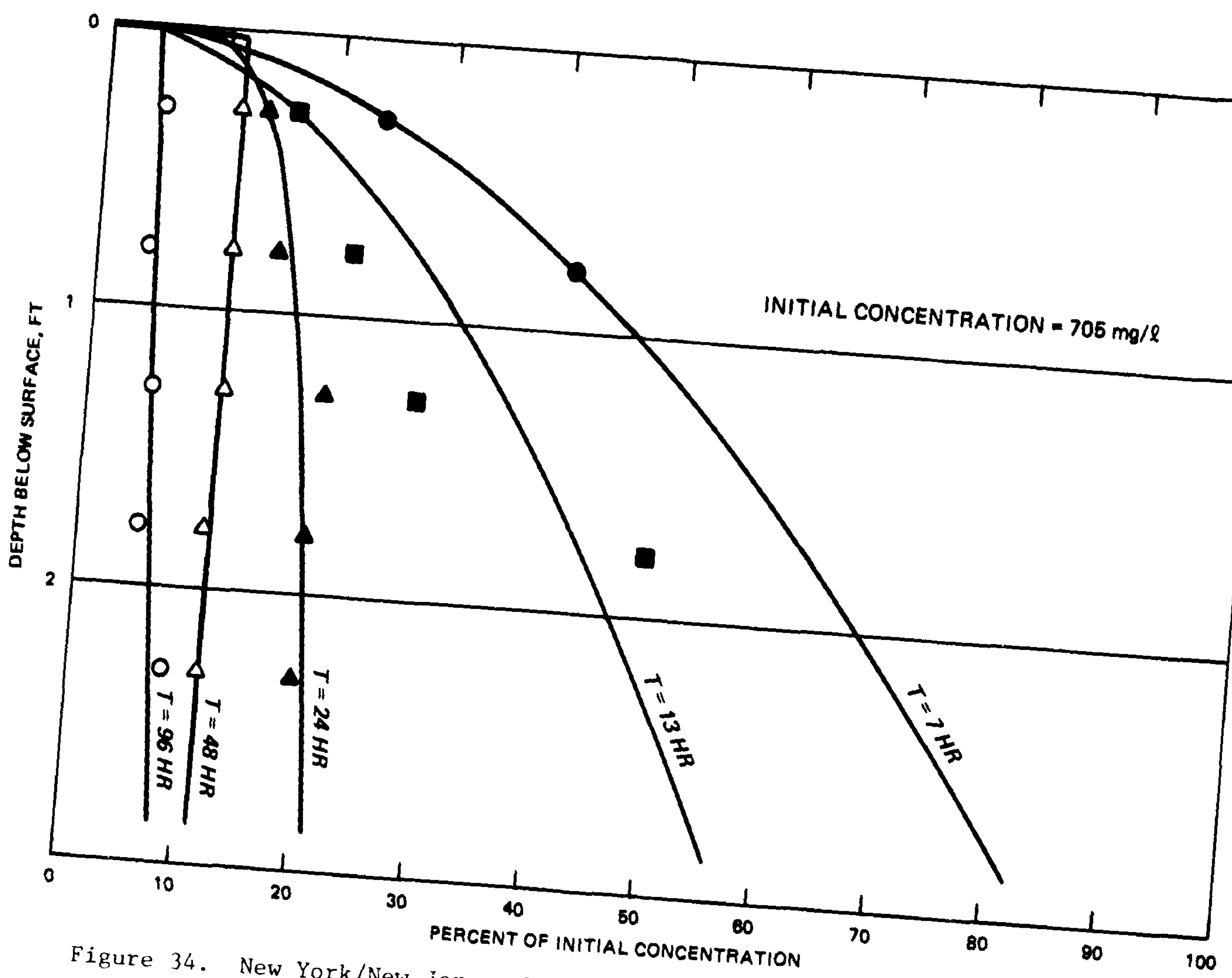


Figure 34. New York/New Jersey Harbor supernatant flocculent settling data

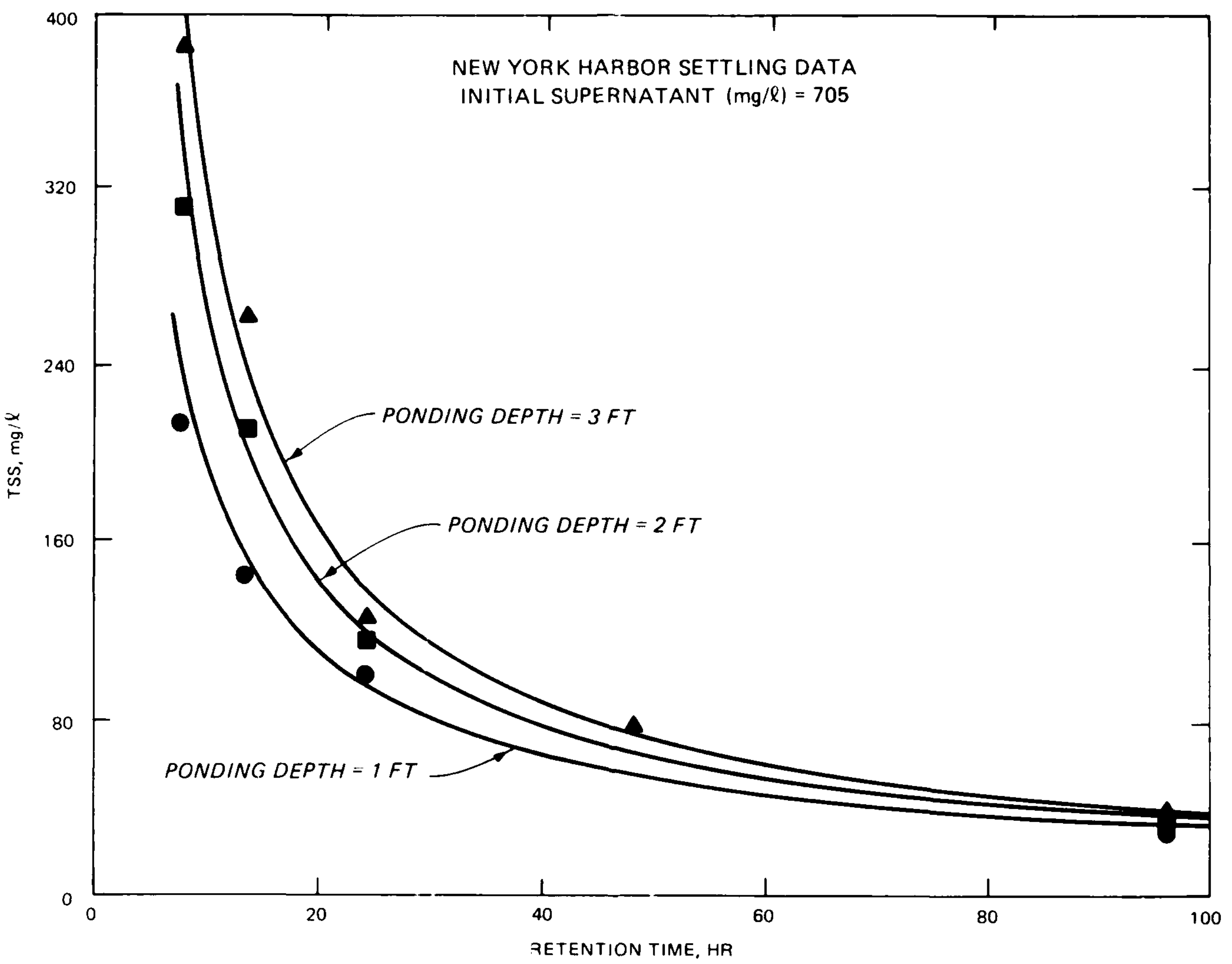


Figure 35. New York/New Jersey Harbor effluent quality as a function of ponding depth and retention time

supernatant is produced. This limiting flow rate for effective clarification is calculated from the area for settling and the zone settling velocity.

127. The second process is thickening of settled solids. The thickening of settled solids is also governed by the zone settling characteristics of the dredged material. The maximum flow rate for effective thickening of settled solids is calculated from the solids loading curve shown in Figure 32 and the compression settling data shown in Figure 33.

128. The third process is initial storage of settled solids. The 15-day compression settling test data are used to calculate the flow rate that will completely fill the volume available for settled solids. Containment areas designed for repeated use generally yield very large limiting flows for this process.

129. The calculated maximum mean daily flows for each of the three processes are given in Table 25 for each containment area. The mean daily flow rate is calculated as shown below:

$$Q_{md} = \frac{Q_i \times T_i}{24} \qquad (1)$$

where

Q_{md} = mean daily flow, cfs

Q_i = pumping inflow rate, cfs

T_i = daily duration of inflow pumping, hr/day

Effluent quality

130. In calculations of effluent quality, the ponding depth for all the containment areas was assumed to be 2 ft. For each containment area, the effluent suspended solids concentration was determined for a range of inflow rates lower than the limiting flow calculated above. The ADDAMS model computes the effluent quality by calculating a detention time corresponding to the given inflow rate and then picking a corresponding effluent suspended solids concentration from the appropriate curve in Figure 35. This concentration corresponds to the effluent quality under ideal quiescent conditions. However, containment areas rarely show quiescent conditions, and there is generally some resuspension of settled solids caused by the effects of wind and waves. The suspended solids concentrations are therefore corrected by multiplying them by the appropriate resuspension factor from Table 24.

Table 25

Limiting Design Flows for Containment Areas

Site	Design Characteristics		
	Settled Solids Thickening Max. Mean Daily Flow, cfs	Supernatant Clarification Max. Mean Daily Flow, cfs	Initial Settled Solids Volume Max. Mean Daily Flow, cfs
Containment island (cofferdam dike)	495.7	177.8	$\geq 1 \times 10^7$*
Containment island (sand dikes)	40.1	41.7	$\geq 1 \times 10^7$
Raritan Bay	>353.5**	>99.5**	$\geq 1 \times 10^7$
Newark Bay	167.9	55.5	$\geq 1 \times 10^7$
Bowery Bay	45.9	23.3	$\geq 1 \times 10^7$
Flushing Bay	32.8	19.1	702,908

* Maximum field width in ADDAMS output for this parameter is 9,999,999.99 cfs.

** These numbers were calculated using a settling area of 280 acres instead of 335 acres. Use of the higher settling area caused the ADDAMS iterative solution routine to become divergent so that no solution was found.

The resuspension factors were chosen from guidance given in Environmental Effects of Dredging Technical Note EEDP-04-3 (EL 1985). The predicted effluent suspended solids concentrations are given as a function of inflow rate for each containment area in Table 26 and Figure 36.

Contaminants in Effluent

Dissolved contaminants

131. The dissolved contaminant concentrations in containment area effluents are estimated from the modified elutriate test. The predicted dissolved concentration for each parameter is given in Table 27. The estimated effluent dissolved concentration is equal to the mean of the measured modified elutriate dissolved concentrations. These dissolved contaminant concentrations were compared with reference water (background) concentrations and Federal water quality criteria.

Comparison of dissolved modified elutriate results and Federal criteria

132. General. In accordance with the Decisionmaking Framework (Lee et al. 1985), the estimated effluent dissolved contaminant concentrations (dissolved modified elutriate test results) were compared with reference water concentrations and Federal water quality criteria for protection of saltwater aquatic life. For those parameters for which Federal criteria (EPA "Redbook" Guidelines) exist, the chronic and acute criteria, reference concentrations, and dissolved modified elutriate results are summarized in Table 28. Table 29 summarizes the reference and test concentrations for those parameters for which there were no criteria (EPA "Redbook") and for which the test concentrations exceeded the background. For the majority of parameters analyzed (137 of 160), either the test results were below the background, or both the background and test results were below detection limits.

133. Test results were evaluated in terms of whether the reference water concentrations were exceeded by the test results, and if so, comparison of test results was made with Federal water quality criteria. The reference water was assumed to be the same as the receiving water. For this comparison, the reference water concentrations were assumed to be equal to those concentrations determined for the water sample collected for purposes of conducting the modified elutriate tests as described in Parts III and V.

Table 26

Predicted Effluent Suspended Solids Concentrations

Site	Mean Daily Flow cfs	Predicted Effluent Suspended Solids* mg/ℓ
Containment island (cofferdam dikes)	45.0	63
	33.8	49
	28.1	42
	22.5	35
	16.9	27
	11.3	20
	5.6	11
Containment island (sand dikes)	40.1**	192
	33.8	166
	28.1	143
	22.5	118
	16.9	93
	11.3	66
	5.6	38
Raritan Bay	45.0	88
	33.8	69
	28.1	59
	22.5	49
	16.9	38
	11.3	27
	5.6	15
Newark Bay	45.0	167
	33.8	131
	28.1	112
	22.5	93
	16.9	73
	11.3	52
	5.6	29
Bowery Bay	23.3**	149
	22.5	145
	16.9	114
	11.3	81
	5.6	45
Flushing Bay	19.1**	149
	16.9	134
	11.3	96
	5.6	53

* Predicted effluent suspended solids are corrected for resuspension effects in containment areas.

** Indicates maximum acceptable flow rate for effective solids removal.

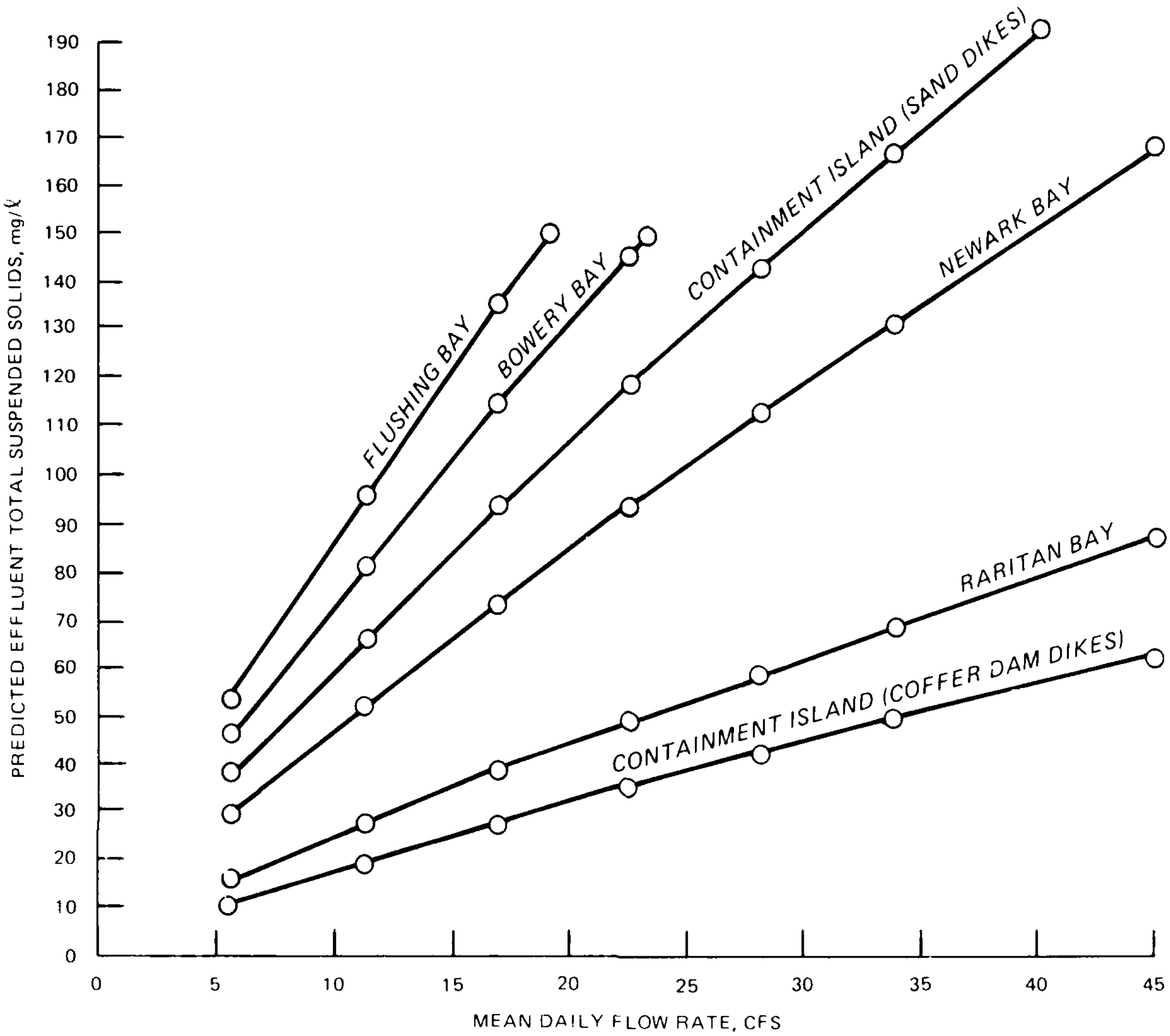


Figure 36. Predicted effluent suspended solids as a function of mean daily flow rate

134. In cases where the elutriate concentrations exceeded criteria or background, a dilution factor was calculated using procedures given in the Decisionmaking Framework. The dilution factor is an indication of the volume required for dilution of the effluent concentration to a target concentration, either a criterion or a value close to background. When the background exceeds appropriate criteria or when no criteria exist, it is theoretically impossible to dilute the effluent concentration to the background. For those cases, a dilution factor was calculated for dilution of the effluent concentration to a value near the background level (arbitrarily defined as 10 percent above background).

Table 27

Predicted Effluent Concentrations for Each Contaminant

							Worst-Case Predicted Effluent Contaminant Concentrations, ppm or mg/ℓ									
							Containment Island (Cofferdam)		Containment Island (Sand Dikes)		Raritan Bay		Newark Bay		Bowery Bay and Flushing Bay	
Parameter Number	Parameter	Symbol	C_{dis} ppm	S_D mg/ℓ	$\bar{F}_{ss}$ ppm	S_F mg/kg	C_{pac}	C_{tot}	C_{pac}	C_{tot}	C_{pac}	C_{tot}	C_{pac}	C_{tot}	C_{pac}	C_{tot}
1	Antimony	Sb														
2	Arsenic	As	0.006	0.001	0.000138	0.000076	0.008659	0.014659	0.0266	0.0326	0.012771	0.018117	0.023045	0.029045	0.020597	0.026597
3	Asbestos	AB														
4	Beryllium	Be														
5	Cadmium	Cd	0.003	0.00195	-0.000012	0.000005	0	0.003	0	0.003	0	0.003	0	0.003	0	0.003
6	Chromium	Cr	0.004	0.0017	0.000098	0.000038	0.006116	0.010116	0.018788	0.022788	0.008559	0.012559	0.016277	0.020277	0.014548	0.018548
7	Copper	Cu	0.0498	0.01025	-0.000038	0.000273	0	0.049833	0	0.049833	0	0.049833	0	0.049833	0	0.049833
8	Cyanide	Cn														
9	Lead	Pb	0.00367	0.00058	0.000021	0.00005	0.00131	0.004976	0.004023	0.007690	0.001833	0.005499	0.003485	0.007152	0.003115	0.006782
10	Mercury	Hg	0.00047	0.00012	0.000006	0.000002	0.000354	0.000821	0.001088	0.001555	0.000496	0.000962	0.000943	0.001409	0.000843	0.001309
11	Nickel	Ni	0.11467	0.0257	-0.000072	0.00017	0	0.144667	0	0.114667	0	0.114667	0	0.114667	0	0.114667
12	Selenium	Se	<0.005	0	--	--	--	--	--	--	--	--	--	--	--	--
13	Silver	Ag	0.0023	0.00058	0.000001	0.000015	0	0.002333	0	0.002333	0	0.002333	0	0.002333	0	0.002333
14	Thallium	Tl														
15	Zinc	Zn	0.0945	0.044	-0.000091	0.000162	0	0.0945	0	0.0945	0	0.0945	0	0.0945	0	0.0945
16	Aluminum	Al														
17	Barium	Ba	0.6542	0.0326	-0.001871	0.000411	0	0.6542	0	0.6542	0	0.6542	0	0.6542	0	0.6542
18	Boron	B														
19	Calcium	Ca	284.7	17.79	0.430620	0.483955	26.96	311.62	82.81	367.47	37.72	322.39	71.74	356.41	64.12	348.79
20	Cobalt	Co														
21	Iron	Fe														
22	Magnesium	Mg	829.7	15.95	1.484007	0.698475	92.898	922.578	285.37	1,115.04	129.999	959.67	247.24	1,076.90	220.97	1,050.64
23	Manganese	Mn														
24	Molybdenum	Mo														
25	Potassium	K	288	7	1.013448	0.363663	63.44	351.44	194.89	482.89	88.78	376.78	168.84	456.84	150.90	438.90
26	Sodium	Na	6826.7	30.6	4.440368	2.248864	277.97	7,104.63	853.88	7,680.55	388.98	7,215.64	739.77	7,566.43	661.17	7,487.84
27	Total Kjeldahl Nitrogen	TKN	52.58	1.49	0.014383	0.020096	0.900374	53.48	2.77	55.35	1.26	53.84	2.40	54.98	2.14	54.72
28	Total Phosphorus	TP														
29	Orthophosphate	OPO-4	0.0237	0.0136	0.003935	0.001229	0.0246349	0.270015	0.756755	0.780421	0.344731	0.368397	0.655618	0.679285	0.585963	0.609630
30	Nitrite Nitrogen	NO2-N	<0.01	0	>0.0012	0.001043	>0.075142	0.085142	>0.230826	0.240826	>0.10515	0.11515	>0.199977	0.209977	>0.178731	0.188731
31	Nitrate Nitrogen	No3-N	<0.0105	0.0009	>0.000089	0.000137	>0.005545	0.016045	>0.017033	0.027533	>0.007759	0.018259	>0.014757	0.025257	>0.013189	0.023689
32	Ammonia Nitrogen	NH3-N	44.9	1.47	0.012499	0.022113	0.782423	45.68	2.404	47.3	1.09	45.99	2.08	46.98	1.86	46.76
33	Hexachlorocyclohexane	AXCCLXA														
34	Hexachlorocyclohexane	BXCCLXB														
35	Hexachlorocyclohexane	DXCCLXD														
36	Aldrin	ALDRIN	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
37	A-BHC	A-BHC	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
38	B-BHC	B-BHC	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	C	<0.00001

(Continued)

*Note: C_{dis} = *mean value of triplicate-filtered samples in modified elutriate test* = predicted dissolved contaminant effluent concentration.

S_D = standard deviation of modified elutriate filtered samples.

$\bar{F}_{ss}$ = mean value of F_{ss} values calculated from unfiltered modified elutriate test results using Equation 6-2.

S_F = standard deviation of F_{ss} values.

C_{pac} = predicted effluent concentration of particle-associated contaminant: calculated using Equation 6-3.

$C_{tot} = C_{dis} + C_{pac}$.

(Sheet 1 of 4)

Table 27. (Continued)

Parameter Number	Parameter	Symbol	C_{dis} ppm	S_D mg/ℓ	$\bar{F}_{ss}$ ppm	S_F mg/kg	Containment Island (Cofferdam) C_{pac}	Containment Island (Cofferdam) C_{tot}	Containment Island (Sand Dikes) C_{pac}	Containment Island (Sand Dikes) C_{tot}	Raritan Bay C_{pac}	Raritan Bay C_{tot}	Newark Bay C_{pac}	Newark Bay C_{tot}	Bowery Bay and Flushing Bay C_{pac}	Bowery Bay and Flushing Bay C_{tot}
							Worst-Case Predicted Effluent Contaminant Concentrations, ppm or mg/ℓ									
39	G-BHC	G-BHC	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
40	D-BHC	D-BHC	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
41	Chlordane	CLDANE	<0.0002	0	0	0	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002
42	PPDDD	PPDDD	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
43	PPDDE	PPDDE	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
44	PPDDT	PPDDT	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
45	Dieldrin	DLDRN	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
46	A-Endosulfan	DNDOI	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
47	B-Endosulfan	ENDOII	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
48	Endosulfan sulfate	ENDOSU	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
49	Endrin	ENDRIN	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
50	Endrin Aldehyde	ENDALD	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
51	Heptachlor	HPTCL	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
52	Hetachlor Epoxide	HPTCLE	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
53	PCB-1016	PCB016	<0.0002	0	0	0	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002
54	PCB-1221	PCB221	<0.0002	0	0	0	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002
55	PCB-1232	PCB232	<0.0002	0	0	0	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002
56	PCB-1242	PCB242	<0.0002	0	0	0	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002
57	PCB-1248	PCB248	<0.0002	0	0	0	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002
58	PCB-1254	PCB254	<0.0002	0	0	0	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002
59	PCB-1260	PCB260	<0.0002	0	0	0	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002
60	Toxaphene	Toxaph	<0.0002	0	0	0	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002	0	<0.0002
61	Phenol	PHENOL	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
62	2-Chlorophenol	CLPHEN	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
63	2-Nitrophenol	2NIPHE	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
64	2, 4-Dimethylphenol	DMEPHE	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
65	2, 4-Dichlorophenol	DCLPHE	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
66	4-Chloro-3-Methyl-phenol	CLMEPH	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
67	2, 4, 6-Trichloro-phenol	TCLPHE	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
68	2, 4-Dinitrophenol	DNIPHE	<0.1	0	0	0	0	<0.1	0	<0.1	0	<0.1	0	<0.1	0	<0.1
69	4-Nitrophenol	4NIPHE	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
70	2-Methyl-4 6-Dini-trophenol	MDNPHE	<0.1	0	0	0	0	<0.1	0	<0.1	0	<0.1	0	<0.1	0	<0.1
71	Pentachlorophenol	PCLPHE	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
72	Chloromethane	CLME														
73	Bromomethane	BRME														
74	Vinyl Chloride	VICL														
75	Chloroethane	CLET														
76	Methylene Chloride	MECL														
77	1, 1-Dichloroethene	DCLETE														
78	1, 1-Dichloroethane	11DCE														
79	Trans-1 2-Dichloro-ethene	+DICLE														
80	Chloroform	CHCL3														
81	1, 2-Dichloroethane	12DCE														
82	1, 1, 1-Trichloro-ethane	111TCA														
83	Carbon Tetra-chloride	C CL 4														
84	Bromodichloro-methane	BRCL2M														

(Continued)

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Table 27. (Continued)

Parameter Number	Parameter	Symbol	C_{dis} ppm	S_D mg/ℓ	$\bar{F}_{ss}$ ppm	S_F mg/kg	Containment Island (Cofferdam) C_{pac}	Containment Island (Cofferdam) C_{tot}	Containment Island (Sand Dikes) C_{pac}	Containment Island (Sand Dikes) C_{tot}	Raritan Bay C_{pac}	Raritan Bay C_{tot}	Newark Bay C_{pac}	Newark Bay C_{tot}	Bowery Bay and Flushing Bay C_{pac}	Bowery Bay and Flushing Bay C_{tot}
							Worst-Case Predicted Effluent Contaminant Concentrations, ppm or mg/ℓ									
85	1,2-Dichloropropane	DICLPR														
86	Trans-1, 3-Dichloropropene	TCLPRE														
87	Trichloroethene	TCLETF														
88	Dibromochloromethane	DBRCLM														
89	Cis-1, 3-Dichloropropene	CCLPRF														
90	1, 1, 2-Trichloroethane	112TCA														
91	Benzene	BENZEN														
92	2-Chloroethylvinylether	CLETRE														
93	Bromoform	CHBR3														
94	1,1,2,2-Tetrachloroethane	TCLETA														
95	Tetrachloroethane	TCLETE														
96	Toluene	TOULEN														
97	Chlorobenzene	CLBEN														
98	Ethylbenzene	ETBEN														
99	Acrolein	ACRO														
100	Acrylonitrile	ACRY														
101	N-Nitrosodimethylamine	ADMEAM	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
102	Bis (2-Chloroisopropyl) Ether	CLISOE	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
103	N-Nitroso-Di-N-Propylamine	NDRPAM	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
104	Nitrobenzene	NIBEN	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
105	Isophorone	ISOPHO	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
106	Bis (2-Chloroethoxy) Methane	CLETMA	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
107	2,6-Dinitrotoluene	26DNT	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
108	2,4-Dinitrotoluene	24DNT	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
109	1,2-Diphenylhydrazine	DPHHYD	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
110	Benzidine	BNEZID	<0.1	0	0	0	0	<0.1	0	<0.1	0	<0.1	0	<0.1	0	<0.1
111	3,3'Dichlorobenzidine	DCLBEZ	<0.1	0	0	0	0	<0.1	0	<0.1	0	<0.1	0	<0.1	0	<0.1
112	Bis (2-Chloroethyl) Ether	BLCETE	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
113	1,3-Dichlorobenzene	MDCLBE	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
114	1,4-Dichlorobenzene	PDCLBE	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
115	1,2-Dichlorobenzene	ODCLBE	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
116	Hexachlorethane	HCLETA	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
117	1,3 4-Trichlorobenzene	TCLBEN	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
118	Nephthalene	NAPHTH	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
119	Hexachlorobutadiene	HCLBU	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
120	Hexachlorocyclopentadiene	HCLEPD	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01

(Continued)

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Table 27. (Concluded)

Parameter Number	Parameter	Symbol	C_{dis} ppm	S_D mg/ℓ	$\bar{F}_{ss}$ ppm	S_F mg/kg	Containment Island (Cofferdam) C_{pac}	Containment Island (Cofferdam) C_{tot}	Containment Island (Sand Dikes) C_{pac}	Containment Island (Sand Dikes) C_{tot}	Raritan Bay C_{pac}	Raritan Bay C_{tot}	Newark Bay C_{pac}	Newark Bay C_{tot}	Bowery Bay and Flushing Bay C_{pac}	Bowery Bay and Flushing Bay C_{tot}
							Worst-Case Predicted Effluent Contaminant Concentrations, ppm or mg/ℓ									
121	2-Chloronaphthalene	CLNAPH	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
122	Acenaphthlyene	ACENAY	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
123	Dimethyl Phthalate	DMEPHT	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	0.01
124	Acenaphthene	ACENAP	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	0.01	0	0.01
125	Fluorene	FLUORE	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	0.01	0	0.01
126	Diethyl Phthalate	DETPHT	<0.05	0	0	0	0	<0.05	0	<0.05	0	<0.05	0	0.05	0	0.05
127	4-Chlorophenyl Phenyl Ether	CPPETH	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	0.01	0	0.01
128	N-Nitrosodiphenyl Amine	NDIPAM	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	0.01	0	0.01
129	4-Bromophenyl Ether	BRPHPE	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	0.01	0	0.01
130	Hexachlorobenzene	HCLBEN	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	0.01	0	0.01
131	Phenanthrene	PHENAN	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	0.01	0	0.01
132	Anthracene	ANTRAC	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	0.01	0	0.01
133	Dibutylphthalate	BUPHTH	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	0.01	0	0.01
134	Fluoranthene	FANTHE	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	0.01	0	0.01
135	Pyrene	PYRENE	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	0.01	0	0.01
136	Butylbenzylphthalate	BUBPHY	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
137	Chrysene	CHRYSE	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
138	Benzo(a)Anthracene	BAANTH	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
139	Bis(2-Ethylhexyl) Phthalate	ETHEPH	<0.01	0	0.000056	0.000098	0.00353	<0.0135	0.0108	<0.0208	0.00494	<0.0149	0.00939	<0.0194	0.00839	<0.0784
140	Di-N-Octylphthalate	DIOPHT	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
					0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
141	Benzo(b)Fluoranthene	BEHFLU	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
142	Benzo(k)Fluoranthene	BEKFLU	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
143	Benzo(a)Pyrene	BEZPYR	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
144	Indeno (1 2 3-C D) Pyrene	INDPYR	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
145	Dibenzo(A H)Anthracene	BEAANT	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
146	Benzo(G H I)Perylene	BEPERY	<0.01	0	0	0	0	<0.01	0	<0.01	0	<0.01	0	<0.01	0	<0.01
147	Sulfite	SO-3														
148	Sulfate	SO-4	1,750	138.9	--	--	--	--	--	--	--	--	--	--	--	--
149	Chlorides	CL	14,567	57.74	--	--	--	--	--	--	--	--	--	--	--	--
150	Total Organic Carbon	TOC														
151	Total Inorganic Carbon	TIC														
152	Total Carbon	TC														
153	Cyanide	CN														
154	Chemical Oxygen Demand	COD														
155	Biochemical Oxygen Demand	BOD														
15[illegible]	Total Suspended Solids	TSS	57.3	3.06	0.31109	0.186593	19.47	76.81	59.82	117.16	27.25	84.58	51.83	109.16	46.32	103.65
158	Methoxychlor	METOXC	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
159	2,4-D	24-D	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001
160	2,4,5-TP	245-TP	<0.00001	0	0	0	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001	0	<0.00001

(Sheet 4 of 4)

Table 28

Comparison of Receiving Water and Modified Elutriate Test Concentrations with Federal Water Quality Criteria

Contaminant	Federal Criteria for Protection of Aquatic Life*: 24-hr Average (Chronic) µg/ℓ	Federal Criteria for Protection of Aquatic Life*: Maximum at Any Time (Acute) µg/ℓ	Receiving Water Concentration (Background)** µg/ℓ	Dissolved Modified Elutriate Concentration** µg/ℓ	Remarks†
Aldrin	--	1.3	<0.1	<0.1	Test < criterion
Cadmium	4.5	59	<0.8	3	Test < criteria
Chromium (VI)	18	1,260	<7	<4	Test < criteria
Copper	4.0	23	11	49.8	D = 3.2 to acute criterion; D = 35.5 to background + 10%
Dieldrin	0.0019	0.71	<0.01	<0.01	D = 5.3 to chronic criterion††
DDT	0.0010	0.13	<0.01	<0.01	D = 10.0 to chronic criterion††
Endosulfan	0.0087	0.034	<0.02	<0.02	D = 2.3 to chronic criterion††
Endrin	0.0023	0.037	<0.01	<0.01	D = 4.3 to chronic criterion††
Heptachlor	0.0036	0.053	<0.01	<0.01	D = 2.8 to chronic criterion††
Lindane (G-BHC)	--	0.16	<0.01	<0.01	Test < criterion
Lead	25	668	1.0	3.7	Test < criteria
Mercury	0.025	3.7	<0.2	0.47	D = 18.8 to chronic criterion (assuming background negligible)
Nickel	71	140	22	115	D = 1.9 to chronic criterion
PCB (total)	0.030	0.030	<0.2	<0.2	D = 6.7 to chronic criterion††
Selenium	54	410	<5	<5	Test < criteria
Silver	--	2.3	31.5	2.3	Background > acute criterion; test = acute criterion.
Toxaphene	--	0.070	<0.2	<0.2	D = 2.9 to acute criterion
Zinc	58	170	46	94.5	D = 4.0 to chronic criterion

* Federal Register, Vol 45, No 231, Friday, 28 November 1980, pp 79318-79357.
** < sign indicates that concentration was below detection limit. The numberical value shown is the detection limit.
† D = dilution factor.
†† Assuming background concentration is negligible and effluent concentration equal to the detection limit. If the background concentration is above zero, but below the chronic criterion, the required dilution will be larger than that which has been calculated here.

Table 29

Comparison of Receiving Water and Dissolved Modified Elutriate Results

Contaminant	Reference Water Concentration µg/ℓ	Dissolved Modified Elutriate Concentration, µg/ℓ	Dilution Factor Required to Reach 10% Above Reference
Arsenic	0.005	0.006	2.0
Barium	0.3145	0.6542	10.8
Total Kjeldahl nitrogen	0.41	52.6	1,270.0
Ammonia nitrogen	0.057	44.9	7,870.0
Diethyl phthalate	<0.005	0.047	84.0

135. Parameters with criteria. Table 28 summarizes the comparisons for parameters for which Federal water quality criteria exist. The detection limits used in the tests were above the criteria for some parameters. For these comparisons, conservative assumptions were made regarding the possible concentrations in the background water and the effluent.

136. Both the modified elutriate and reference concentrations were below the criteria for aldrin, cadmium, chromium, lindane, lead, and selenium. These contaminants therefore require no dilution or controls for the dissolved form.

137. Modified elutriate and background water concentrations for total PCB and toxaphene were below detection limits; however, the detection limits were above the criteria. The effluent concentrations may or may not exceed the background concentrations and/or criteria for these parameters. Assuming that background concentrations are zero and effluent concentrations are equal to the detection limit, a dilution factor of 6.7 is required to dilute the effluent concentration for total PCB to the chronic criterion. A dilution factor of 2.9 is required for toxaphene to dilute the effluent concentration to the acute criterion (toxaphene has no chronic criterion).

138. Modified elutriate and background water concentrations for dieldrin, DDT, endosulfan, endrin, and heptochlor were below detection limits;

however, the detection limits were between the chronic and acute criteria. The effluent will therefore meet the acute criterion for these parameters but may or may not exceed the background and/or chronic criterion. Assuming the background concentrations are zero and effluent concentrations are equal to the detection limits, the required dilutions to reach the chronic criteria are 5.3, 10.0, 2.3, 4.3, and 2.8 for dieldrin, DDT, endosulfan, endrin, and heptachlor, respectively. If background concentrations are above zero but below the chronic criteria, the required dilutions to meet the criteria will be larger.

139. The modified elutriate concentration for mercury was below the acute criterion but exceeded the chronic criterion. The background water concentration for mercury was below the detection limit, but the limit exceeded the chronic criterion. Mercury therefore meets the acute criterion but exceeds both the background and chronic criterion. If the background concentration is below the chronic criterion, it will be possible to dilute the effluent to meet the chronic criterion. Assuming that the background concentration is zero, a dilution factor of 18.8 is required. Assuming that the background is equal to the detection limit, a dilution factor of 13.5 is required to dilute the effluent to a value 10 percent above the background.

140. The modified elutriate concentration for copper exceeded both the background and acute and chronic criteria. However, the background concentration also exceeded the chronic criterion. A dilution factor of 3.2 is required to meet the acute criterion, and a dilution factor of 35.5 is required to dilute the effluent to a value 10 percent above the background.

141. The background concentration for silver was higher than both the modified elutriate concentration and the criteria. No control for silver in the dissolved form is therefore required.

142. The modified elutriate concentrations for nickel and zinc exceeded the chronic criteria. Background concentrations were below the chronic criteria. Dilution factors of 1.9 and 4.0 are required to dilute the effluent to the chronic criteria for nickel and zinc, respectively.

143. Parameters with no criteria. Table 29 summarizes the parameters for which there are no criteria and for which the estimated effluent concentration exceeds the background. For arsenic, barium, and diethyl phthalate, dilution factors of 2.0, 10.8, and 84.0, respectively, are required to dilute

the estimated effluent concentration of 10 percent above the background concentration.

144. Calculated dilution factors for total Kjeldahl nitrogen (TKN) and ammonia nitrogen are excessive, indicating that dilution of these parameters to concentrations near background cannot be achieved in a mixing zone of reasonable size. Effluent controls will be required to remove dissolved concentrations to below background levels.

145. Summary. In summary, either the estimated effluent concentrations were below the reference water concentrations, or both were below detection for 137 of 160 parameters analyzed. An additional seven parameters either were below the background or exceeded the background but were below the Federal chronic criteria. Sixteen remaining parameters were of concern.

146. A dilution factor less than 10.0 would result in dilution of the effluent concentration to the chronic criterion for dieldrin, DDT, endosulfan, endrin, heptachlor, nickel, total PCB, and zinc and to the acute criterion for toxaphene (no chronic criterion). Mercury would require a dilution factor of 18.8 to the acute criterion. Dilution factors of 2.0, 10.8, and 35.5 would result in dilution of the effluent concentration to 10 percent above the background concentration for arsenic, barium, and copper, respectively. The required dilution for these parameters could be achieved within a reasonable mixing zone. The dimensions of the required mixing zone would be dependent on site-specific receiving water hydrodynamic conditions and the effluent flow conditions. A dilution factor of 84.0 was calculated for diethyl phthalate to reach 10 percent above the background. This dilution would require a proportionately larger mixing zone.

147. Estimated effluent concentrations for TKN and ammonia nitrogen greatly exceeded the background concentrations. Effluent control measures would be required to reduce the dissolved concentrations of these parameters to concentrations below background.

Particle-associated contaminants

148. The suspended solids in the effluent also carry an associated load of contaminants. The total contaminant concentrations, including the particle-associated fractions, were calculated for the "worst case" operational condition for each alternative.

149. The fraction of each contaminant in the total suspended solids is calculated as follows:

$$F_{ss} = (1 \times 10^6) \frac{C_{unfiltered} - C_{filtered}}{TSS} \qquad (2)$$

where

F_{ss} = fraction of contaminant in the total suspended solids, milligrams of contaminant per kilogram of suspended solids

$C_{unfiltered}$ = total contaminant concentration in modified elutriate sample, mg/ℓ

$C_{filtered}$ = dissolved contaminant concentration in modified elutriate sample, mg/ℓ

TSS = total suspended solids concentration in modified elutriate sample, mg/ℓ

The concentration of particle-associated contaminant in the containment area effluent can be estimated once the expected effluent total suspended solids concentration is known. The particle-associated contaminant concentration is estimated as:

$$C_{pac} = \frac{F_{ss} \times TSS_{eff}}{1 \times 10^6} \qquad (3)$$

where

C_{pac} = particle-associated contaminant concentration, mg/ℓ

TSS_{eff} = predicted total suspended solids in containment area effluent, mg/ℓ

150. It should be noted that in some cases the unfiltered contaminant concentration appeared to be lower than the filtered value (because of limits of experimental accuracy or particle interference in the chemical analysis). This gives rise to a negative value of F_{ss} in Equation 2. Since this is a physical impossibility, all negative values of F_{ss} were set to zero for use in Equation 3.

151. The predicted total effluent contaminant concentrations are shown in Table 27. These concentrations were calculated assuming the highest effluent TSS concentrations given for each site in Table 26. The predictions therefore assume that the mean daily inflow to each site is either 45 cfs or the highest acceptable flow rate for the site if that value is lower than

45 cfs. There are no criteria or standards for comparison of total contaminant concentrations. These results were therefore not considered in the selection of site control measures.

Floating contaminants

152. During the sedimentation testing, it was observed that a scum formed on the surface of the supernatant water. This scum consisted of a film of oil and small agglomerates of particulate matter. The agglomerates were buoyed up by a combination of oil and water surface tension effects and small gas bubbles. The gas bubbles may have come from air entrained when the slurry was mixed and pumped into the columns and/or from anaerobic chemical reactions. It was observed that a minor agitation of the supernatant surface was sufficient to break the surface tension effects that attached the bubbles to the sediment agglomerates. The bubbles then burst at the surface, and nearly all the sediment sank to the interface between settled solids and supernatant water. Since the surface of a CDF is nearly always agitated by wind-induced waves, it is felt that floating sediment agglomerates will be unable to persist. However, during a sustained period of extremely calm weather, they can cause a significant degradation of effluent water quality unless control measures are implemented.

153. The formation of an oil slick on the supernatant surface is a more persistent problem. The sediment samples from Newtown Creek and Upper Gowanus Bay were all observed to be very oily, and a certain amount of this oil will likely float on the CDF water surface during disposal operations. The modified elutriate results show the concentrations of dissolved and suspended contaminants in the water column; they do not, however, include the concentrations of contaminants associated with the floating oil. Since hydrocarbons are generally much more soluble in oil than in water, the floating oil may provide a significant increase in effluent PAH contaminant concentrations above those predicted by the modified elutriate test. This problem can be largely cured by installing an oil-absorbent boom or other oil-skimmer system to remove oil before it passes over the effluent weir.

PART VIII: CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

Conclusions

Microbial pathogens

154. Based on the results of this study, the following conclusions regarding the fate of microbial pathogens are made:

- a. The following microorganisms were found to be present in the New York/ New Jersey sediment (number per gram dry weight of sediment):
  - (1) *Escherichia coli*--18,200.
  - (2) *Streptococcus faecalis*--32,250.
  - (3) *Clostridium perfringens*--650,000.
  - (4) Total fecal coliforms--66,000.
  - (5) Total fecal streptococci--32,250 .
  - (6) Total heterotrophic bacteria--1,270,000.
- b. A significant portion of the fecal coliforms and fecal streptococci remains in the water column at 96 hr in the microbial pathogens sedimentation test.
- c. The numbers of these organisms in the water column decrease with increasing time and in synchrony with the settling sediment. The coefficient of distribution between settling of these organisms and sedimentation of particulate matter is from 0.74 to 0.87 percent, depending on the organism being examined.
- d. The number of indicator organisms declines with time in suspended sediment held at 20° C. However, the rate of decline is species and pH dependent.

Sedimentation

155. Based on the results of this study, the following conclusions are made regarding the design requirements for sedimentation:

- a. The maximum anticipated dredging flow rate (daily average) is 45 cfs. Based on the settling test results, the maximum allowable flow rates for the sites under consideration are: Flushing Bay (19.1 cfs), Bowery Bay (23.3 cfs), Newark Bay (55.5 cfs), Raritan Bay (99.5 cfs), containment island with sand dikes (40.7 cfs), and containment island with cofferdams (177.8 cfs). Some restrictions on maximum anticipated dredging flow rates will therefore be required if Flushing Bay, Bowery Bay, or the containment island with sand dikes is the only available disposal area.
- b. The worst case predicted effluent suspended solids concentrations for the sites under consideration are: Flushing Bay

(149 mg/ℓ), Bowery Bay (149 mg/ℓ), Newark Bay (167 mg/ℓ), Raritan Bay (88 mg/ℓ), containment island with sand dikes (192 mg/ℓ), and containment island with cofferdams (63 mg/ℓ). These concentrations correspond to either the maximum allowable flow rate for the respective site as shown in a above or the maximum anticipated flowrate of 45 cfs, whichever is lower.

Storage capacity

156. Based on the results of this study, the following conclusions are made regarding filling rates and storage capacity:

a. The service life of the proposed containment island is projected to be a maximum of 23 years if sand retaining dikes are used, whereas the service life will be approximately 100 years (90 years with no dewatering and 139 years with dewatering) if cofferdam dikes are used.

b. The service lives of the four nearshore containment areas vary from a minimum of 9 years at Flushing Bay to a maximum of 52 years at Raritan Bay when no dewatering of dredged material is considered. With dredged material dewatering, the potential service lives vary from 10 years at Flushing Bay to 69 years at Raritan Bay.

Effluent water quality

157. Estimated chemical effluent water quality for dissolved contaminant concentrations is the same for all alternatives considered. Based on the results of this study, the following conclusions are made regarding effluent water quality:

a. Based on modified elutriate test results, either the estimated effluent contaminant concentrations are below the reference water concentrations, or both test results and reference concentrations are below detection for 137 of 160 parameters analyzed. An additional seven parameters either are below the background or exceeded the background but are below the Federal chronic criterion. A total of 16 remaining parameters are of concern.

b. A dilution factor less than 10.0 will result in dilution of the effluent concentration to the chronic criterion for dieldrin, DDT, endosulfan, endrin, heptachlor, nickel, total PCB, and zinc, and to the acute criterion for toxaphene (no chronic criterion). The calculation of required dilutions for dieldrin, DDT, endosulfan, endrin, heptachlor, and total PCB assumes that the background concentrations of these contaminants are zero. If the background concentrations are significantly higher than zero, the required dilutions can be larger than 10. The test results show that the effluent concentrations of all these contaminants, other than PCB, are below the acute criteria. For PCB, the detection limit is above the acute criterion. Mercury requires a dilution factor of 18.8

to the acute criterion. Dilution factors of 2.0, 10.8, and 35.5 result in dilution of the effluent concentration to 10 percent above the background concentration for arsenic, barium, and copper, respectively. The required dilution for these parameters can be achieved within a reasonable mixing zone. The dimensions of the required mixing zone will be dependent on site-specific receiving water hydrodynamic conditions and effluent flow conditions.

c. A dilution factor of 84.0 has been calculated for diethyl phthalate to reach 10 percent above the background. This dilution requires a proportionately larger mixing zone.

d. Estimated effluent concentrations for TKN and ammonia nitrogen greatly exceed the background concentrations. Effluent control measures will be required to reduce the dissolved concentrations of these parameters to concentrations below background.

e. Estimated suspended solids concentrations in the effluent also exceed background concentrations for higher effective flow rates. Either restrictions on dredge size or production rates or control measures such as a chemical clarification will be required to reduce the concentrations. Chemical clarification also has the added benefit of reducing particle-associated contaminant concentrations in the effluent.

Recommended effluent control measures

158. Various site control measures are generally required when it is anticipated that unacceptable levels of suspended sediments or contaminants may be released in the effluent. The requirement for site control measures is determined by analyses of the sediments to be contained, disposal operations, and CDF characteristics. Although some of the parameters that are used to indicate the need for site control measures were addressed during this study, others were not addressed. Additionally, some of the evaluations of parameters conducted in this study were, of necessity, not site specific but general in nature. For this reason, any conclusions concerning site control measures should be considered as interim guidance and should be used only to indicate the direction for future work and investigations.

159. No conclusions can be reached concerning the need for site control measures for control of total suspended solids since no standards for comparison are available. If site control measures are needed, typical effluent controls at conventional CDFs are generally limited to chemical clarification designed to provide additional removal (above that resulting from sedimentation) of suspended solids and associated adsorbed contaminants (Schroeder 1983). Additional controls can be used to remove fine particulates that will

not settle or to remove soluble contaminants from the effluent. Examples of these technologies are filtration, adsorption, ion exchange, chemical oxidation, and biological treatment processes. Beyond chemical clarification, only limited data exist for treatment of dredged material (Gambrell, Khalid, and Patrick 1978).

160. The effluent from the CDFs was evaluated with regard to dissolved contaminants to determine whether site control measures are needed for this aspect of the operation. Site control measures are required to remove dissolved TKN and ammonia nitrogen from the effluent water in order to reduce concentrations to below background. Appropriate control measures for such treatment have not been evaluated for dredged material. If the decision to implement such controls is made, more detailed studies will be required.

161. The sediment samples from Newtown Creek and Gowanus Bay were extremely oily. When the composite sediment sample was diluted for sedimentation testing, it was observed that some of the oil floated on the surface of the supernatant. It may therefore be necessary to install oil skimmers near the CDF discharge weir to prevent the chemically contaminated floating oil from being discharged with the effluent water.

162. A significant level of microorganisms remained in the water column through 96 hr; these were available for discharge with any effluents released from the CDF prior to this time. Whether or not this is a problem depends to a large extent on the numbers of these microorganisms present in the water where CDF construction is anticipated. If large numbers are already present, any additional microorganisms contributed by effluents from the CDF may not be significant. On the other hand, if few of these organisms are present before construction of the disposal facility, then it is recommended that any effluent being discharged from the CDF prior to 96 hr be chlorinated. However, caution is necessary. During laboratory testing, the water column retains both a yellowish coloration and a frothy appearance at the surface at 96 hr. This suggests that considerable organic matter may remain in soluble form in the water column. Organic compounds were also observed in the modified elutriate test results. This material may react adversely with the chlorine to form trihalomethanes.

163. A more detailed analysis of the modified elutriate test results is advisable. Specific analyses should consider the types of PAHs and organic degradation products present in order to identify what additional treatment

measures may be necessary. Because the exact nature of the organic matter is unknown, chlorination of the water should not be undertaken without further examining the water to determine the potential for trihalomethane formation during the chlorination process.

Recommendations for Further Studies

164. The Phase I studies described in this report address the contaminant pathway associated with discharge of contaminants including microbic pathogens in effluents during active disposal operations. Subsequent studies should address the remaining contaminant pathways associated with CDFs as described in the Management Strategy. These pathways include: surface runoff due to precipitation, leachate into ground water or adjacent surface water, and direct uptake by plants and animals colonizing the site. Additional evaluations of the fate of pathogens are also recommended. Brief descriptions of these pathways and associated testing protocols taken from the Management Strategy are given in the following paragraphs.

Testing

165. Microbial pathogens. Survival tests conducted as part of the microbial pathogens work demonstrated that, under aerobic conditions, there generally are predictable declines in the levels of key indicator species at pH 6.0, 7.0, and 8.0. The effects on survival of other environmental conditions, including variations in oxidation-reduction (redox) potential and moisture content, were beyond the original time and cost allowances for these tests. However, these factors can exert major influences on the survival of microbial pathogens in a CDF environment and should be examined. An examination of the effect of variation in redox potential on survival can be easily accomplished with the use of controlled Eh/pH reactors available at WES. In like manner, an examination of the effect of desiccation on survival can be conducted with the use of a specially fabricated drying chamber, designed to permit slow, steady drying under closely controlled temperatures. Results of these tests will give a more complete picture of the fate of microbial pathogens in the CDF environment. These results will also provide guidance for constructing and managing the CDF to minimize the impact of survival and movement of microbial pathogens on ambient water quality.

166. Surface runoff quality. After dredged material has been placed in a confined disposal site and the dewatering process has been initiated, contaminant mobility in rainfall-induced runoff is considered in the overall environmental impact of the dredged material being placed in a CDF. The quality of the runoff water can vary depending on the physicochemical process and the contaminants present in the dredged material. Drying and oxidation will promote microbiological activity, which breaks down the organic component of the dredged material and oxidizes sulfide compounds to more soluble sulfate compounds. Concurrently, reduced iron compounds will become oxidized, and iron oxides will be formed. These iron oxides can act as metal scavengers to absorb soluble metals and render them less soluble. The pH of the dredged material will be affected by the amount of acid-forming compounds present as well as the amount of basic compounds that can buffer acid formation. Generally, large amounts of sulfur, organic matter, and pyrite material will generate acid conditions. Basic components of dredged material, such as calcium carbonate, will tend to neutralize the acidity produced. The resulting pH of the dredged material will depend on the relative amounts of acid formed and the basic compounds present.

167. Runoff water quality will depend on the results of the above processes as the dredged material dries out. For example, should there be more acid formation than the amount of basic compounds present to neutralize the acid, then the dredged material will become acidic. Excessive amounts of pyrite when oxidized can reduce pH values from an initial pH 7 down to pH 3. Under these conditions, surface runoff water quality can be acidic and can contain elevated concentrations of metals.

168. An appropriate test for evaluating surface runoff water quality must consider the effects of the drying process to adequately estimate and predict runoff water quality. At present, there is no single simple laboratory test to predict runoff water quality. A laboratory test using a rainfall simulator has been developed (Westerdahl and Skogerboe 1981) and is being used to predict surface runoff water quality from dredged material as part of the CE/USEPA Field Verification (FVP) Program (Lee and Skogerboe 1983a, 1983b). This test protocol involves taking a sediment sample from a waterway and placing it in a soil-bed lysimeter in its original wet reduced state. The sediment is then allowed to dry out. At intervals during the drying process,

rainfall events are applied to the lysimeter, and surface runoff water samples are collected and analyzed for selected water quality parameters. Rainfall simulations are repeated on the soil-bed lysimeter until the sediment has completely dried out. Results of the tests can be used to predict the surface runoff water quality that can be expected in a confined disposal site when the dredged material dries out. From these results, control measures can be formulated to treat surface runoff water if required to minimize the environmental impact to surrounding areas.

169. Leachate quality. Subsurface drainage or seepage through dikes from CDFs may reach adjacent aquifers or adjacent surface waters. Fine-grained dredged material tends to form its own disposal-area liner as particles settle with percolation drainage water, but the settlement process may require some time for self-sealing to develop. Since most contaminants potentially present in dredged material are closely adsorbed to particles, only the dissolved fraction will be present in leachates. A potential for leachate impacts exists when a dredged material is placed in a confined site adjacent to ground-water aquifers. The site-specific nature of subsurface conditions is the major factor in determining possible impact (Chen et al. 1978).

170. A predictive protocol for leachate quality in CDFs is under development at the WES. In its current state of development, the protocol involves both experimental leaching tests and procedures for extrapolating the laboratory leaching data to the field situation using predictive equations. The laboratory tests are therefore developmental in nature. These developmental tests consist of anaerobic and aerobic sequential and/or graded sequential batch leaching tests on the sediment. In sequential batch leaching tests, sediment is challenged by fresh leaching solution over time instead of being continually exposed to the same solution. In graded sequential batch leaching tests, different sediment-to-water ratios are used in the batch testing. These tests allow identification of the critical factors influencing contaminant mobility and quantification of release rates under varying environmental conditions. Pressure column permeameter leaching tests should also be conducted to demonstrate the validity of batch testing results.

171. Plant uptake. After dredged material has been placed in either an intertidal, wetland, or upland environment, plants can invade and colonize the site. In most cases, fine-grained dredged material contains large amounts of nitrogen and phosphorus, which tend to promote vigorous growth of plants on

dredged material placed in confined disposal sites at elevations that range from wetland to upland terrestrial environments. In many cases, the dredged material has been placed in confined disposal sites because contaminants are present in the dredged material. There is potential for movement of contaminants from the dredged material into plants and then eventually into the food chain.

172. An appropriate test for evaluating plant uptake of contaminants from dredged material must consider the ultimate environment in which the dredged material is placed and the physicochemical processes governing the availability of contaminants for plant uptake. There is a test protocol that was developed under the Long-Term Effects of Dredging (LEDO) Program based on the results of the Dredged Material Research Program (DMRP). This procedure has been applied to testing a number of contaminated dredged materials and has given appropriate results and information to predict the potential for plant uptake of contaminants from dredged material (Folsom and Lee 1981, 1983; Folsom, Lee, and Preston 1981; Lee, Folsom, and Engler 1982). The procedure is presently being field verified under the FVP.

173. The procedure requires taking a sample of sediment from a waterway and placing it in either a flooded wetland environment or an upland terrestrial environment in the laboratory. An index plant, *Cyperus esculentus*, is then grown in the sediment under conditions of both wetland and upland environments. Plant growth, phytotoxicity, and bioaccumulation of contaminants are monitored during the growth period. Plants are harvested and analyzed for contaminants. The test results indicate the potential for plants to become contaminated when grown on the dredged material in either a wetland or an upland terrestrial environment. From the test results, appropriate management strategies can be formulated as to where to place dredged material to minimize plant uptake.

174. Another laboratory test being developed under the LEDO Program uses an organic extractant of dredged material to predict plant uptake of certain trace metals such as zinc, cadmium, nickel, chromium, lead, and copper (Lee, Folsom, and Bates 1983). This test procedure attempts to simulate the capacity of a plant root to extract metals from dredged material. Field verification of this test protocol is being conducted under the FVP.

Animal uptake

175. Animals have also been known to invade and colonize confined (intertidal, wetland, and upland) dredged material disposal sites. In some cases, prolific wildlife habitats have become established on these sites. Concern has developed recently about the potential for animals inhabiting either wetland or upland terrestrial confined disposal sites to become contaminated and contribute to the contamination of food chains associated with the site.

176. An appropriate test for evaluating animal uptake of contaminants from dredged material must consider the ultimate environment in which the dredged material is placed and the physicochemical processes governing the biological availability of contaminants for animal uptake. Currently, a test protocol being developed under the FVP uses an earthworm as an index species to indicate toxicity and bioaccumulation of contaminants from dredged material. In this procedure, an earthworm is placed in sediment maintained in moist and semimoist, air-dried environments. The toxicity and bioaccumulation of contaminants are monitored over a 28-day period (Simmers, Rhett, and Lee 1983).

Potential site controls

177. Based on the results of Phase II testing, recommendations can be made on site controls for contaminant pathways other than effluent quality. These may include controls for leachate, surface runoff, or plant and animal uptake. Leachate controls consist of measures to minimize ground-water pollution by preventing mobilization of soluble contaminants. Control measures include site selection, dewatering to minimize leachate production, chemical admixing to prevent or retard leaching, lining the site to prevent leakage and seepage, capping the surface to minimize infiltration and thereby leachate production, and leachate collection, treatment, or recycling (Gambrell, Khalid, and Patrick 1978).

178. Each site should be evaluated with regard to the potential for leaching or seepage of contaminated water through the retaining dikes as well as seepage through the foundation soil. The exact nature of the dike construction material and the degree of soil compaction to be expected must be ascertained. These items, in conjunction with the water table levels inside and outside the dikes, will significantly affect the quantity of seepage to be expected. The quantity of seepage and the concentration of contaminants

carried by that seepage will dictate whether or not some type of leachate/ seepage control will be required at the various containment areas.

179. When dredged material is allowed to dewater, oxidation of some contaminants will occur; this oxidation results in contaminants that are more bioavailable than are reduced particle-associated contaminants. No evaluations made as a part of this study would permit determination of required site control measures for this scenario. Two approaches have been widely used at various locations to prevent oxidation or to control release/availability of oxidation products. Prevention can be accomplished by placing the sediment in a submerged environment in which it will not be subjected to evaporative drying. The bioavailability of oxidation products can be controlled by one of several measures. Control measures include selective vegetation to minimize contaminant uptake, liming or chemical treatment to minimize or prevent release of contaminants from the material for uptake by the plants, and capping with clean sediment or excavated material (Gambrell, Khalid, and Patrick 1978). Plant and animal contaminant uptake controls are intended to prevent mobilization of contaminants into the food chain.

180. If the CDFs are operated in such a manner that runoff from the site might occur, then additional site control measures may be needed. Runoff controls consist of measures to prevent the erosion of contaminated dredged material and the dissolution and discharge of contaminants from the oxidized dredged material surface. Site control options include maintaining ponded conditions, planting vegetation to stabilize the surface, liming the surface to prevent acidification and to reduce dissolution, covering the surface with synthetic geomembranes, and/or placing a lift of clean material to cover the contaminated dredged material (Gambrell, Khalid, and Patrick 1978).

181. Several other site control measures may be required if airborne pollutants are a problem. These include gaseous emission control and wind-erosion control. The control of gaseous emissions that might present human health concerns can consist of physical measures such as covers, vertical barriers, control trench vents, pipe vents, and gas-collection systems. Wind-erosion control of contaminated surface materials is another type of management or operating control to minimize transport of contaminants offsite. Techniques for limiting wind erosion are generally similar to those employed in dust control and include physical, chemical, or vegetative stabilization of surface soils (US Army Corps of Engineers 1983).

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APPENDIX A: BULK SEDIMENT CHEMISTRY ANALYSIS

Bulk Sediment Chemistry Analysis
for the New York/New Jersey Harbor Sediment

Parameter Number	Parameter	Symbol	ppm	Duplicate ppm
1	Antimony	SB	--	--
2	Arsenic	AS	31.3	31.9
3	Asbestos	AB	--	--
4	Beryllium	BE	--	--
5	Cadmium	CD	17.2	16.5
6	Chromium	CR	281.0	278.0
7	Copper	CU	1,100.0	1,100.0
8	Cyanide	CN	--	--
9	Lead	PB	344.0	0.0
10	Mercury	HG	0.703	0.703
11	Nickel	NI	326.0	326.0
12	Selenium	SE	1.78	1.88
13	Silver	AG	9.97	9.87
14	Thallium	TL	--	--
15	Zinc	ZN	974.0	971.0
16	Aluminum	AL	--	--
17	Barium	BA	267.0	272.0
18	Boron	B	--	--
19	Calcium	CA	8,910.0	8,660.0
20	Cobalt	CO	--	--
21	Iron	FE	--	--
22	Magnesium	MG	7,070.0	6,950.0
23	Manganese	MN	--	--
24	Molybdenum	MO	--	--
25	Potassium	K	4,440.0	4,300.0
26	Sodium	NA	9,870.0	9,520.0
27	Total Kjeldahl Nitrogen	TKN	3,510.0	3,420.0
28	Total Phosphorus	TP	4,480.0	4,410.0
29	Orthophosphate	OPO-4	11.7	11.4

(Continued)

Bulk Sediment Chemistry Analysis for the New York/New Jersey Harbor Sediment

(Continued)

Parameter Number	Parameter	Symbol	ppm	Duplicate ppm
30	Nitrite Nitrogen	NO2-N	7.72	7.72
31	Nitrate Nitrogen	NO3-N	20.1	19.3
32	Ammonia Nitrogen	NH3-N	387.0	387.0
33	Hexachlorocyclohexane	AXCCLXA	--	--
34	Hexachlorocyclohexane	BXCCLXB	--	--
35	Hexachlorocyclohexane	DXCCLXD	--	--
36	Aldrin	ALDRIN	0.0002	0.0002
37	α-BHC	A-BHC	0.0002	0.0002
38	β-BHC	B-BHC	0.0002	0.0002
39	γ-BHC	G-BHC	0.0002	0.0002
40	δ-BHC	D-BHC	0.0002	0.0002
41	Chlordane	CLDANE	0.002	0.002
42	PPDDD	PPDDD	0.332	0.183
43	PPDDE	PPDDE	0.115	0.079
44	PPDDT	PPDDT	0.198	0.050
45	Dieldrin	DLDRN	0.0223	0.0110
46	A-Endosulfan	ENDOI	0.0002	0.0002
47	B-Endosulfan	ENDOII	0.0002	0.0002
48	Endosulfan Sulfate	ENDOSU	0.0002	0.0002
49	Endrin	ENDRIN	0.0002	0.0002
50	Endrin Aldehyde	ENDALD	0.0002	0.0002
51	Heptachlor	HPTCL	0.0002	0.0002
52	Heptachlor Epoxide	HPTCLE	0.0002	0.0002
53	PCB-1016	PCB016	0.002	0.002
54	PCB-1221	PCB221	0.002	0.002
55	PCB-1232	PCB232	0.002	0.002
56	PCB-1242	PCB242	0.002	0.002
57	PCB-1248	PCB248	1.84	1.61

(Continued)

Bulk Sediment Chemistry Analysis

for the New York/New Jersey Harbor Sediment

(Continued)

Parameter Number	Parameter	Symbol	ppm	Duplicate ppm
58	PCB-1254	PCB254	0.002	0.002
59	PCB-1260	PCB260	0.002	0.002
60	Toxaphene	Toxaph	0.002	0.002
61	Phenol	PHENOL	1.0	1.0
62	2-Chlorophenol	CLPHEN	1.0	1.0
63	2-Nitrophenol	2NIPHE	1.0	1.0
64	2,4-Dimethylphenol	DMEPHE	1.0	1.0
65	2,4-Dichlorophenol	DCLPHE	1.0	1.0
66	4-Chloro-3-Methylphenol	CLMEPH	1.0	1.0
67	2,4,6-Trichlorophenol	TCLPHE	1.0	1.0
68	2,4-Dinitrophenol	DNIPHE	10.0	10.0
69	4-Nitrophenol	4NIPHE	1.0	1.0
70	2-Methyl-4,6-Dinitrophenol	MDNPHE	10.0	10.0
71	Pentachlorophenol	PCLPHE	1.0	1.0
72	Chloromethane	CLME	--	--
73	Bromomethane	BRME	--	--
74	Vinyl Chloride	VICL	--	--
75	Chloroethane	CLET	--	--
76	Methylene Chloride	MECL	--	--
77	1,1-Dichloroethene	DCLETE	--	--
78	1,1-Dichloroethane	11DCE	--	--
79	Trans-1,2-Dichloroethene	+DICLE	--	--
80	Chloroform	CHCL3	--	--
81	1,2-Dichloroethane	12DCE	--	--
82	1,1,1-Trichloroethane	111TCA	--	--
83	Carbon Tetrachloride	C CL 4	--	--
84	Bromodichloromethane	BRCL2M	--	--
85	1,2-Dichloropropane	DICLPR	--	--

(Continued)

Bulk Sediment Chemistry Analysis

for the New York/New Jersey Harbor Sediment

(Continued)

Parameter Number	Parameter	Symbol	ppm	Duplicate ppm
86	Trans-1,3-Dichloropropene	+CLPRE	--	--
87	Trichloroethene	TCLETE	--	--
88	Dibromochloromethane	DBRCLM	--	--
89	Cis-1,3-Dichloropropene	CCLPRE	--	--
90	1,1,2-Trichloroethane	112TCA	--	--
91	Benzene	BENZEN	--	--
92	2-Chloroethylvinylether	CLETRE	--	--
93	Bromoform	CHBR3	--	--
94	1,1,2,2-Tetrachloroethane	TCLETA	--	--
95	Tetrachloroethene	TCLETE	--	--
96	Toluene	TOLUEN	--	--
97	Chlorobenzene	CLBEN	--	--
98	Ethylbenzene	ETBEN	--	--
99	Acrolein	ACRO	--	--
100	Acrylonitrile	ACRY	--	--
101	N-Nitrosodimethylamine	ADMEAM	1.0	1.0
102	Bis(2-Chloroisopropyl)Ether	CLISOE	1.0	1.0
103	N-Nitroso-Di-N-Propylamine	NDRPAM	1.0	1.0
104	Nitrobenzene	NIBEN	1.0	1.0
105	Isophorone	ISOPHO	1.0	1.0
106	Bis(2-Chloroethoxy)Methane	CLETMA	1.0	1.0
107	2,6-Dinitrotoluene	26DNT	1.0	1.0
108	2,4-Dinitrotoluene	24DNT	1.0	1.0
109	1,2-Diphenylhydrazine	DPHHYD	1.0	1.0
110	Benzidine	BENZID	10.0	10.0
111	3,3'Dichlorobenzidine	DCLBEZ	10.0	10.0
112	Bis(2-Chloroethyl)Ether	BCLETE	1.0	1.0
113	1,3-Dichlorobenzene	MDCLBE	1.0	1.0

(Continued)

Bulk Sediment Chemistry Analysis

for the New York/New Jersey Harbor Sediment

(Continued)

Parameter Number	Parameter	Symbol	ppm	Duplicate ppm
114	1,4-Dichlorobenzene	PDCLBE	1.0	1.0
115	1,2-Dichlorobenzene	ODCLBE	1.0	1.0
116	Hexachloroethane	HCLETA	1.0	1.0
117	1,3,4-Trichlorobenzene	TCLBEN	1.0	1.0
118	Naphthalene	NAPHTH	7.36	7.78
119	Hexachlorobutadiene	HCLBU	1.0	1.0
120	Hexachlorocyclopentadiene	HCLEPD	1.0	1.0
121	2-Chloronaphthalene	CLNAPH	1.0	1.0
122	Acenaphthlyene	ACENAY	1.0	1.0
123	Dimethyl Phthalate	DMEPHT	1.0	1.0
124	Acenaphthene	ACENAP	2.75	2.75
125	Fluorene	FLUORE	1.0	1.0
126	Diethyl Phthalate	DETPHT	1.0	1.0
127	4-Chlorophenyl Phenyl Ether	CPPETH	1.0	1.0
128	N-Nitrosodiphenyl Amine	NDIPAM	1.0	1.0
129	4-Bromophenyl Ether	BRPHPE	1.0	1.0
130	Hexachlorobenzene	HCLBEN	1.0	1.0
131	Phenanthrene	PHENAN	14.4	15.2
132	Anthracene	ANTRAC	5.33	4.97
133	Dibutylphthalate	BUPHTH	1.0	1.0
134	Fluoranthene	FANTHE	9.04	8.56
135	Pyrene	PYRENE	13.0	12.8
136	Butylbenzylphthalate	BUBPHY	1.0	1.0
137	Chrysene	CHRYSE	1.0	1.0
138	Benzo(a)Anthracene	BAANTH	1.0	1.0
139	Bis(2-Ethylhexyl)Phthalate	ETHEPH	63.0	62.5
140	Di-N-Octylphthalate	DIOPHT	1.0	1.0
141	Benzo(b)Fluoranthene	BEHFLU	1.0	1.0

(Continued)

Bulk Sediment Chemistry Analysis

for the New York/New Jersey Harbor Sediment

(Concluded)

Parameter Number	Parameter	Symbol	ppm	Duplicate ppm
142	Benzo(k)Fluoranthene	BEKFLU	1.0	1.0
143	Benzo(a)Pyrene	BEZPYR	1.0	1.0
144	Indeno(1,2,3-c,d)Pyrene	INDPYR	1.0	1.0
145	Dibenzo(a,h)Anthracene	BEAANT	1.0	1.0
146	Benzo(g,h,i)Perylene	BEPERY	1.0	1.0
147	Sulfite	SO-3	--	--
148	Sulfate	SO-4	3,360.0	3,390.0
149	Chlorides	CL	17,200.0	17,000.0
150	Total Organic Compound	TOC	--	--
151	Total Inorganic Compound	TIC	--	--
152	Total Carbon	TC	--	--
153	Cyanide	CN	--	--
154	Chemical Oxygen Demand	COD	--	--
155	Biochemical Oxygen Demand	BOD	--	--
156	Total Solids	TS	37.0	0.0
157	Methoxychlor	METOXC	0.448	0.175
158	2,4-D	24-D	0.02	--
159	2,4,5-TP	245-TP	0.02	--

APPENDIX B: BACKGROUND WATER CHEMISTRY TEST RESULTS

Background Water Chemistry Results
for the New York/New Jersey Harbor Project

Parameter Number	Parameter	Symbol	ppm	Duplicate ppm
1	Antimony	SB	--	--
2	Arsenic	AS	<0.005	<0.005
3	Asbestos	AB	--	--
4	Beryllium	BE	--	--
5	Cadmium	CD	<0.0008	--
6	Chromium	CR	0.007	--
7	Copper	CU	0.011	--
8	Cyanide	CN	--	--
9	Lead	PB	<0.001	--
10	Mercury	HG	<0.0002	<0.0004
11	Nickel	NI	0.022	--
12	Selenium	SE	<0.005	<0.005
13	Silver	AG	0.031	0.032
14	Thallium	TL	--	--
15	Zinc	ZN	0.048	0.044
16	Aluminum	AL	--	--
17	Barium	BA	0.314	0.315
18	Boron	B	--	--
19	Calcium	CA	315.0	307.0
20	Cobalt	CO	--	--
21	Iron	FE	--	--
22	Magnesium	MG	1,000.0	982.0
23	Manganese	MN	--	--
24	Molybdenum	MO	--	--
25	Potassium	K	356.0	368.0
26	Sodium	NA	7,760.0	7,800.0
27	Total Kjeldahl Nitrogen	TKN	0.43	0.38
28	Total Phosphorus	TP	<0.1	<0.1
29	Orthophosphate	OPO-4	0.113	0.118

(Continued)

Background Water Chemistry Results

for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	ppm	Duplicate ppm
30	Nitrite Nitrogen	NO2-N	<0.01	<0.01
31	Nitrate Nitrogen	NO3-N	0.257	0.263
32	Ammonia Nitrogen	NH3-N	0.057	0.057
33	Hexachlorocyclohexane	AXCCLXA	--	--
34	Hexachlorocyclohexane	BXCCLXB	--	--
35	Hexachlorocyclohexane	DXCCLXD	--	--
36	Aldrin	ALDRIN	<0.00001	--
37	α-BHC	A-BHC	<0.00001	--
38	β-BHC	B-BHC	<0.00001	--
39	γ-BHC	G-BHC	<0.00001	--
40	δ-BHC	D-BHC	<0.00001	--
41	Chlordane	CLDANE	<0.0002	--
42	PPDDD	PPDDD	<0.00001	--
43	PPDDE	PPDDE	<0.00001	--
44	PPDDT	PPDDT	<0.00001	--
45	Dieldrin	DLDRN	<0.00001	--
46	A-Endosulfan	ENDOI	<0.00001	--
47	B-Endosulfan	ENDOII	<0.00001	--
48	Endosulfan sulfate	ENDOSU	<0.00001	--
49	Endrin	ENDRIN	<0.00001	--
50	Endrin Aldehyde	ENDALD	<0.00001	--
51	Heptachlor	HPTCL	<0.00001	--
52	Heptachlor Epoxide	HPTCLE	<0.00001	--
53	PCB-1016	PCB016	<0.0002	--
54	PCB-1221	PCB221	<0.0002	--
55	PCB-1232	PCB232	<0.0002	--
56	PCB-1242	PCB242	<0.0002	--
57	PCB-1248	PCB248	<0.0002	--

(Continued)

Background Water Chemistry Results for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	ppm	Duplicate ppm
58	PCB-1254	PCB254	<0.0002	--
59	PCB-1260	PCB260	<0.0002	--
60	Toxaphene	Toxaph	<0.0002	--
61	Phenol	PHENOL	<0.005	--
62	2-Chlorophenol	CLPHEN	<0.005	--
63	2-Nitrophenol	2NIPHE	<0.005	--
64	2,4-Dimethylphenol	DMEPHE	<0.005	--
65	2,4-Dichlorophenol	DCLPHE	<0.005	--
66	4-Chloro-3-Methylphenol	CLMEPH	<0.005	--
67	2,4,6-Trichlorophenol	TCLPHE	<0.005	--
68	2,4-Dinitrophenol	DNIPHE	<0.05	--
69	4-Nitrophenol	4NIPHE	<0.005	--
70	2-Methyl-4,6-Dinitrophenol	MDNPHE	<0.05	--
71	Pentachlorophenol	PCLPHE	<0.005	--
72	Chloromethane	CLME	--	--
73	Bromomethane	BRME	--	--
74	Vinyl Chloride	VICL	--	--
75	Chloroethane	CLET	--	--
76	Methylene Chloride	MECL	--	--
77	1,1-Dichloroethene	DCLETE	--	--
78	1,1-Dichloroethane	11DCE	--	--
79	Trans-1,2-Dichloroethene	+DICLE	--	--
80	Chloroform	CHCL3	--	--
81	1,2-Dichloroethane	12DCE	--	--
82	1,1,1-Trichloroethane	111TCA	--	--
83	Carbon Tetrachloride	C CL 4	--	--
84	Bromodichloromethane	BRCL2M	--	--
85	1,2-Dichloropropane	DICLPR	--	--

(Continued)

Background Water Chemistry Results

for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	ppm	Duplicate ppm
86	Trans-1,3-Dichloropropene	+CLPRE	--	--
87	Trichloroethene	TCLETE	--	--
88	Dibromochloromethane	DBRCLM	--	--
89	Cis-1,3-Dichloropropene	CCLPRE	--	--
90	1,1,2-Trichloroethane	112TCA	--	--
91	Benzene	BENZEN	--	--
92	2-Chloroethylvinylether	CLETRE	--	--
93	Bromoform	CHBR3	--	--
94	1,1,2,2-Tetrachloroethane	TCLETA	--	--
95	Tetrachloroethene	TCLETE	--	--
96	Toluene	TOLUEN	--	--
97	Chlorobenzene	CLBEN	--	--
98	Ethylbenzene	ETBEN	--	--
99	Acrolein	ACRO	--	--
100	Acrylonitrile	ACRY	--	--
101	N- Nitrosodimethylamine	ADMEAM	<0.005	--
102	Bis(2-Chloroisopropyl) Ether	CLISOE	<0.005	--
103	N-Nitroso-Di-N-Propylamine	NDRPAM	<0.005	--
104	Nitrobenzene	NIBEN	<0.005	--
105	Isophorone	ISOPHO	<0.005	--
106	Bis(2-Chloroethoxy)Methane	CLETMA	<0.005	--
107	2,6-Dinitrotoluene	26DNT	<0.005	--
108	2,4-Dinitrotoluene	24DNT	<0.005	--
109	1,2-Diphenylhydrazine	DPHHYD	<0.005	--
110	Benzidine	BENZID	<0.05	--
111	3,3'Dichlorobenzidine	DCLBEZ	<0.05	--
112	Bis(2-Chloroethyl)Ether	BCLETE	<0.005	--
113	1,3-Dichlorobenzene	MDCLBE	<0.005	--

(Continued)

Background Water Chemistry Results

for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	ppm	Duplicate ppm
114	1,4-Dichlorobenzene	PDCLBE	<0.005	--
115	1,2-Dichlorobenzene	ODCLBE	<0.005	--
116	Hexachloroethane	HCLETA	<0.005	--
117	1,3,4-Trichlorobenzene	TCLBEN	<0.005	--
118	Naphthalene	NAPHTH	<0.005	--
119	Hexachlorobutadiene	HCLBU	<0.005	--
120	Hexachlorocyclopentadiene	HCLEPD	<0.005	--
121	2-Chloronaphthalene	CLNAPH	<0.005	--
122	Acenaphthlyene	ACENAY	<0.005	--
123	Dimethyl Phthalate	DMEPHT	<0.005	--
124	Acenaphthene	ACENAP	<0.005	--
125	Fluorene	FLUORE	<0.005	--
126	Diethyl Phthalate	DETPHT	<0.005	--
127	4-Chlorophenyl Phenyl Ether	CPPETH	<0.005	--
128	N-Nitrosodiphenyl Amine	NDIPAM	<0.005	--
129	4-Bromophenyl Ether	BRPHPE	<0.005	--
130	Hexachlorobenzene	HCLBEN	<0.005	--
131	Phenanthrene	PHENAN	<0.005	--
132	Anthracene	ANTRAC	<0.005	--
133	Dibutylphthalate	BUPHTH	<0.005	--
134	Fluoranthene	FANTHE	<0.005	--
135	Pyrene	PYRENE	<0.005	--
136	Butylbenzylphthalate	BUBPHY	<0.005	--
137	Chrysene	CHRYSE	<0.005	--
138	Benzo(a)Anthracene	BAANTH	<0.005	--
139	Bis(2-Ethylhexyl)Phthalate	ETHEPH	<0.005	--
140	Di-N-Octylphthalate	DIOPHT	<0.005	--
141	Benzo(b)Fluoranthene	BEHFLU	<0.005	--

(Continued)

Background Water Chemistry Results

for the New York/New Jersey Harbor Project

(Concluded)

Parameter Number	Parameter	Symbol	ppm	Duplicate ppm
142	Benzo(k)Fluoranthene	BEKFLU	<0.005	--
143	Benzo(a)Pyrene	BEZPYR	<0.005	--
144	Indeno(1,2,3-c,d)Pyrene	INDPYR	<0.005	--
145	Dibenzo(a,h)Anthracene	BEAANT	<0.005	--
146	Benzo(g,h,i)Perylene	BEPERY	<0.005	--
147	Sulfite	SO-3	--	--
148	Sulfate	SO-4	2,000.0	2,000.0
149	Chlorides	CL	15,600.0	15,600.0
150	Total Organic Compound	TOC	--	--
151	Total Inorganic Compound	TIC	--	--
152	Total Carbon	TC	--	--
153	Cyanide	CN	--	--
154	Chemical Oxygen Demand	COD	--	--
155	Biochemical Oxygen Demand	BOD	--	--
156	Total Solids	TS	58,727.0	--
157	Total Suspended Solids	TSS	<10.0	--
158	Methoxychlor	METOXC	<0.00001	--
159	2,4-D	24-D	<0.001	--
160	2,4,5-TP	245-TP	<0.001	--

APPENDIX C: FILTERED MODIFIED ELUTRIATE ANALYSIS

Filtered Modified Elutriate Analysis for the New York/New Jersey Harbor Project

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	Dup. of 2	3
1	Antimony	SB					
2	Arsenic	AS	0.006	0.006	0.007		0.005
3	Asbestos	AB					
4	Beryllium	BE					
5	Cadmium	CD	0.005		0.003		0.0011
6	Chromium	CR	0.006		0.003		0.003
7	Copper	CU	0.053	0.058	0.038		0.056
8	Cyanide	CN					
9	Lead	PB	0.004		0.004		0.003
10	Mercury	HG	0.0004	0.0008	0.0004		0.0004
11	Nickel	NI	0.114	0.108	0.091		0.142
12	Selenium	SE	0.005	0.005	0.005		0.005
13	Silver	AG	0.002		0.003		0.002
14	Thallium	TL					
15	Zinc	ZN	0.093	0.086	0.098		0.096
16	Aluminum	AL					
17	Barium	BA	0.620	0.615	0.665		0.680
18	Boron	B					
19	Calcium	CA	274.0	270.0	277.0		305.0

(Continued)

Filtered Modified Elutriate Analysis

for the New Ycrk/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	Dup. of 2	3
20	Cobalt	CO					
21	Iron	FE					
22	Magnesium	MG	821.0	823.0	819.0		848.0
23	Manganese	MN					
24	Molybdenum	MO					
25	Potassium	K	290.0	280.0	296.0		283.0
26	Sodium	NA	6,810.0	6,790.0	6,820.0		6,860.0
27	Total Kjeldahl Nitrogen	TKN	51.4	52.1	51.7		54.3
28	Total Phosphorus	TP	2.03		2.08	2.10	1.78
29	Orthophosphate	OPO-4	0.021	0.017	0.039		0.013
30	Nitrite Nitrogen	NO2-N	0.01	0.01	0.01		0.01
31	Nitrate Nitrogen	NO3-N	0.012	0.011	0.01		0.01
32	Ammonia Nitrogen	NH3-N	44.0	44.2	44.0		46.6
33	Hexachlorocyclohexane	AXCCLXA					
34	Hexachlorocyclohexane	BXCCLXB					
35	Hexachlorocyclohexane	DXCCLXD					
36	Aldrin	ALDRIN	0.00001		0.00001		0.0000'
37	α-BHC	A-BHC	0.00001		0.00001		0.00001

(Continued)

Filtered Modified Elutriate Analysis for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	Dup. of 2	3
38	β-BHC	B-BHC	0.00001		0.00001		0.00001
39	γ-BHC	G-BHC	0.00001		0.00001		0.00001
40	δ-BHC	D-BHC	0.00001		0.00001		0.00001
41	Chlordane	CLDANE	0.0002		0.0002		0.0002
42	PPDDD	PPDDD	0.00001		0.00001		0.00001
43	PPDDE	PPDDE	0.00001		0.00001		0.00001
44	PPDDT	PPDDT	0.00001		0.00001		0.00001
45	Dieldrin	DLDRN	0.00001		0.00001		0.00001
46	A-Endosulfan	ENDOI	0.00001		0.00001		0.00001
47	B-Endosulfan	ENDOII	0.00001		0.00001		0.00001
48	Endosulfan sulfate	ENDOSU	0.00001		0.00001		0.00001
49	Endrin	ENDRIN	0.00001		0.00001		0.00001
50	Endrin Aldehyde	ENDALD	0.00001		0.00001		0.00001
51	Heptachlor	HPTCL	0.00001		0.00001		0.00001
52	Heptachlor Epoxide	HPTCLE	0.00001		0.00001		0.00001
53	PCB-1016	PCB016	0.0002		0.0002		0.0002
54	PCB-1221	PCB221	0.0002		0.0002		0.0002
55	PCB-1232	PCB232	0.0002		0.0002		0.0002

(Continued)

Filtered Modified Elutriate Analysis for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	Dup. of 2	3
56	PCB-1242	PCB242	0.0002		0.0002		0.0002
57	PCB-1248	PCB248	0.0002		0.0002		0.0002
58	PCB-1254	PCB254	0.0002		0.0002		0.0002
59	PCB-1260	PCB260	0.0002		0.0002		0.0002
60	Toxaphene	Toxaph	0.0002		0.0002		0.0002
61	Phenol	PHENOL	0.01	0.01	0.01		0.01
62	2-Chlorophenol	CLPHEN	0.01	0.01	0.01		0.01
63	2-Nitrophenol	2NIPHE	0.01	0.01	0.01		0.01
64	2,4-Dimethylphenol	DMEPHE	0.01	0.01	0.01		0.01
65	2,4-Dichlorophenol	DCLPHE	0.01	0.01	0.01		0.01
66	4-Chloro-3-Methylphenol	CLMEPH	0.01	0.01	0.01		0.01
67	2,4,6-Trichlorophenol	TCLPHE	0.01	0.01	0.01		0.01
68	2,4-Dinitrophenol	DNIPHE	0.1	0.1	0.1		0.1
69	4-Nitrophenol	4NIPHE	0.01	0.01	0.01		0.01
70	2-Methyl-4,6-Dinitrophenol	MDNPHE	0.1	0.1	0.1		0.1
71	Pentachlorophenol	PCLPHE	0.01	0.01	0.01		0.01
72	Chloromethane	CLME					
73	Bromomethane	BRME					

(Continued)

Filtered Modified Elutriate Analysis for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	Dup. of 2	3
74	Vinyl Chloride	VICL					
75	Chloroethane	CLET					
76	Methylene Chloride	MECL					
77	1,1-Dichloroethene	DCLETE					
78	1,1-Dichloroethane	11DCE					
79	Trans-1,2-Dichloroethene	+DICLE					
80	Chloroform	CHCL3					
81	1,2-Dichloroethane	12DCE					
82	1,1,1-Trichloroethane	111TCA					
83	Carbon Tetrachloride	C CL 4					
84	Bromodichloromethane	BRCL2M					
85	1,2-Dichloropropane	DICLPR					
86	Trans-1,3-Dichloropropene	+CLPRE					
87	Trichloroethene	TCLETE					
88	Dibromochloromethane	DBRCLM					
89	Cis-1,3-Dichloropropene	CCLPRE					
90	1,1,2-Trichloroethane	112TCA					
91	Benzene	BENZEN					

(Continued)

Filtered Modified Elutriate Analysis

for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	Dup. of 2	3
92	2-Chloroethylvinylether	CLETRE					
93	Bromoform	CHBR3					
94	1,1,2,2-Tetrachloroethane	TCLETA					
95	Tetrachloroethene	TCLETE					
96	Toluene	TOLUEN					
97	Chlorobenzene	CLBEN					
98	Ethylbenzene	ETBEN					
99	Acrolein	ACRO					
100	Acrylonitrile	ACRY					
101	N-Nitrosodimethylamine	ADMEAM	0.01	0.01	0.01		0.01
102	Bis(2-Chloroisopropyl)Ether	CLISOE	0.01	0.01	0.01		0.01
103	N-Nitroso-Di-N-Propylamine	NDRPAM	0.01	0.01	0.01		0.01
104	Nitrobenzene	NIBEN	0.01	0.01	0.01		0.01
105	Isophorone	ISOPHO	0.01	0.01	0.01		0.01
106	Bis(2-Chloroethoxy)Methane	CLETMA	0.01	0.01	0.01		0.01
107	2,6-Dinitrotoluene	26DNT	0.01	0.01	0.01		0.01
108	2,4-Dinitrotoluene	24DNT	0.01	0.01	0.01		0.01
109	1,2-Diphenylhydrazine	DPHHYD	0.01	0.01	0.01		0.01

(Continued)

Filtered Modified Elutriate Analysis

for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	Dup. of 2	3
110	Benzidine	BENZID	0.1	0.1	0.1		0.1
111	3,3'Dichlorobenzidine	DCLBEZ	0.1	0.1	0.1		0.1
112	Bis(2-Chloroethyl)Ether	BCLETE	0.01	0.01	0.01		0.01
113	1,3-Dichlorobenzene	MDCLBE	0.01	0.01	0.01		0.01
114	1,4-Dichlorobenzene	PDCLBE	0.01	0.01	0.01		0.01
115	1,2-Dichlorobenzene	ODCLBE	0.01	0.01	0.01		0.01
116	Hexachloroethane	HCLETA	0.01	0.01	0.01		0.01
117	1,3,4-Trichlorobenzene	TCLBEN	0.01	0.01	0.01		0.01
118	Naphthalene	NAPHTH	0.01	0.01	0.01		0.01
119	Hexachlorobutadiene	HCLBU	0.01	0.01	0.01		0.01
120	Hexachlorocyclopentadiene	HCLEPD	0.01	0.01	0.01		0.01
121	2-Chloronaphthalene	CLNAPH	0.01	0.01	0.01		0.01
122	Acenaphthlyene	ACENAY	0.01	0.01	0.01		0.01
123	Dimethyl Phthalate	DMEPHT	0.01	0.01	0.01		0.01
124	Acenaphthene	ACENAP	0.01	0.01	0.01		0.01
125	Fluorene	FLUORE	0.01	0.01	0.01		0.01
126	Diethyl Phthalate	DETPHT	0.12	0.12	0.01		0.01
127	4-Chlorophenyl Phenyl Ether	CPPETH	0.01	0.01	0.01		0.01

(Continued)

Filtered Modified Elutriate Analysis

for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	Dup. of 2	3
128	N-Nitrosodiphenyl Amine	NDIPAM	0.01	0.01	0.01		0.01
129	4-Bromophenyl Ether	BRPHPE	0.01	0.01	0.01		0.01
130	Hexachlorobenzene	HCLBEN	0.01	0.01	0.01		0.01
131	Phenanthrene	PHENAN	0.01	0.01	0.01		0.01
132	Anthracene	ANTRAC	0.01	0.01	0.01		0.01
133	Dibutylphthalate	BUPHTH	0.01	0.01	0.01		0.01
134	Fluoranthene	FANTHE	0.01	0.01	0.01		0.01
135	Pyrene	PYRENE	0.01	0.01	0.01		0.01
136	Butylbenzylphthalate	BUBPHY	0.01	0.01	0.01		0.01
137	Chrysene	CHRYSE	0.01	0.01	0.01		0.01
138	Benzo(a)Anthracene	BAANTH	0.01	0.01	0.01		0.01
139	Bis(2-Ethylhexyl)Phthalate	ETHEPH	0.01	0.01	0.01		0.01
140	Di-N-Octylphthalate	DIOPHT	0.01	0.01	0.01		0.01
141	Benzo(b)Fluoranthene	BEHFLU	0.01	0.01	0.01		0.01
142	Benzo(k)Fluoranthene	BEKFLU	0.01	0.01	0.01		0.01
143	Benzo(a)Pyrene	BEZPYR	0.01	0.01	0.01		0.01
144	Indeno(1,2,3-c,d)Pyrene	INDPYR	0.01	0.01	0.01		0.01
145	Dibenzo(a,h)Anthracene	BEAANT	0.01	0.01	0.01		0.01

(Continued)

Filtered Modified Elutriate Analysis
for the New York/New Jersey Harbor Project
(Concluded)

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	Dup. of 2	3
146	Benzo(g,h,i)Perylene	BEPERY	0.01	0.01	0.01		0.01
147	Sulfite	SO-3					
148	Sulfate	SO-4	1,670.0	1,650.0	1,680.0		1,910.0
149	Chlorides	CL	14,600.0	14,400.0	14,600.0		14,600.0
150	Total Organic Compound	TOC					
151	Total Inorganic Compound	TIC					
152	Total Carbon	TC					
153	Cyanide	CN					
15	Chemical Oxygen Demand	COD					
155	Biochemical Oxygen Demand	BOD					
156	Total Solids	TS	42,382.0		43,222.0		43,353.0
157	Total Suspended Solids	TSS	54.0		60.0		58.0
158	Methoxychlor	METOXC	0.00001		0.00001		0.00001
159	2,4-D	24-D	0.00001		0.00001		0.00001
160	2,4,5-TP	245-TP	0.00001		0.00001		0.00001

APPENDIX D: UNFILTERED MODIFIED ELUTRIATE ANALYSIS

Unfiltered Modified Elutriate Analysis

for the New York/New Jersey Harbor Project

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	3
1	Antimony	SB				
2	Arsenic	AS	0.019	0.019	0.022	0.012
3	Asbestos	AB				
4	Beryllium	BE				
5	Cadmium	CD	0.0022		0.0018	0.0021
6	Chromium	CR	0.021		0.009	0.010
7	Copper	CU	0.080	0.082	0.030	0.043
8	Cyanide	CN				
9	Lead	PB	0.010		0.007	0.001
10	Mercury	HG	0.0008	0.0020	0.0008	0.0008
11	Nickel	NI	0.133	0.126	0.101	0.104
12	Selenium	SE				
13	Silver	AG	0.003		0.001	0.003
14	Thallium	TL				
15	Zinc	ZN	0.085	0.086	0.076	0.099
16	Aluminum	AL				
17	Barium	BA	0.489	0.481	0.502	0.503
18	Boron	B				
19	Calcium	CA	294.0	289.0	303.0	356.0

(Continued)

Unfiltered Modified Elutriate Analysis

for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	3
20	Cobalt	CO				
21	Iron	FE				
22	Magnesium	MG	929.0	924.0	933.0	990.0
23	Manganese	MN				
24	Molybdenum	MO				
25	Potassium	K	360.0	360.0	377.0	375.0
26	Sodium	NA	7,180.0	7,200.0	7,060.0	7,340.0
27	Total Kjeldahl Nitrogen	TKN	53.5	54.4	52.3	55.2
28	Total Phosphorus	TP				
29	Orthophosphate	OPO-4	0.385	0.390	0.402	0.277
30	Nitrite Nitrogen	NO2-N	0.067	0.066	0.180	0.064
31	Nitrate Nitrogen	NO3-N	0.014	0.010	0.028	0.011
32	Ammonia Nitrogen	NH3-N	46.6	45.7	44.3	47.5
33	Hexachlorocyclohexane	AXCCLXA				
34	Hexachlorocyclohexane	BXCCLXB				
35	Hexachlorocyclohexane	DXCCLXD				
36	Aldrin	ALDRIN	0.00001		0.00001	0.00001
37	α-BHC	A-BHC	0.00001		0.00001	0.00001

(Continued)

Unfiltered Modified Elutriate Analysis

for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	3
38	β-BHC	B-BHC	0.00001		0.00001	0.00001
39	γ-BHC	G-BHC	0.00001		0.00001	0.00001
40	δ-BHC	D-BHC	0.00001		0.00001	0.00001
41	Chlordane	CLDANE	0.0002		0.0002	0.0002
42	PPDDD	PPDDD	0.00001		0.00001	0.00001
43	PPDDE	PPDDE	0.00001		0.00001	0.00001
44	PPDDT	PPDDT	0.00001		0.00001	0.00001
45	Dieldrin	DLDRN	0.00001		0.00001	0.00001
46	A-Endosulfan	ENDOI	0.00001		0.00001	0.00001
47	B-Endosulfan	ENDOII	0.00001		0.00001	0.00001
48	Endosulfan sulfate	ENDOSU	0.00001		0.00001	0.00001
49	Endrin	ENDRIN	0.00001		0.00001	0.00001
50	Endrin Aldehyde	ENDALD	0.00001		0.00001	0.00001
51	Heptachlor	HPTCL	0.00001		0.00001	0.00001
52	Heptachlor Epoxide	HPTCLE	0.00001		0.00001	0.00001
53	PCB-1016	PCB016	0.0002		0.0002	0.0002
54	PCB-1221	PCB221	0.0002		0.0002	0.0002
55	PCB-1232	PCB232	0.0002		0.0002	0.0002

(Continued)

Unfiltered Modified Elutriate Analysis

for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	3
56	PCB-1242	PCB242	0.0002		0.0002	0.0002
57	PCB-1248	PCB248	0.0002		0.0002	0.0002
58	PCB-1254	PCB254	0.0002		0.0002	0.0002
59	PCB-1260	PCB260	0.0002		0.0002	0.0002
60	Toxaphene	Toxaph	0.0002		0.0002	0.0002
61	Phenol	PHENOL	0.01		0.01	0.01
62	2-Chlorophenol	CLPHEN	0.01		0.01	0.01
63	2-Nitrophenol	2NIPHE	0.01		0.01	0.01
64	2,4-Dimethylphenol	DMEPHE	0.01		0.01	0.01
65	2,4-Dichlorophenol	DCLPHE	0.01		0.01	0.01
66	4-Chloro-3-Methylphenol	CLMEPH	0.01		0.01	0.01
67	2,4,6-Trichlorophenol	TCLPHE	0.01		0.01	0.01
68	2,4-Dinitrophenol	DNIPHE	0.1		0.1	0.1
69	4-Nitrophenol	4NIPHE	0.01		0.01	0.01
70	2-Methyl-4,6-Dinitrophenol	MDNPHE	0.1		0.1	0.1
71	Pentachlorophenol	PCLPHE	0.01		0.01	0.01
72	Chloromethane	CLME				
73	Bromomethane	BRME				

(Continued)

Unfiltered Modified Elutriate Analysis

for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	3
74	Vinyl Chloride	VICL				
75	Chloroethane	CLET				
76	Methylene Chloride	MECL				
77	1,1-Dichloroethene	DCLETE				
78	1,1-Dichloroethane	11DCE				
79	Trans-1,2-Dichloroethene	+DICLE				
80	Chloroform	CHCL3				
81	1,2-Dichloroethane	12DCE				
82	1,1,1-Trichloroethane	111TCA				
83	Carbon Tetrachloride	C CL 4				
84	Bromodichloromethane	BRCL2M				
85	1,2-Dichloropropane	DICLPR				
86	Trans-1,3-Dichloropropene	+CLPRE				
87	Trichloroethene	TCLETE				
88	Dibromochloromethane	DBRCLM				
89	Cis-1,3-Dichloropropene	CCLPRE				
90	1,1,2-Trichloroethane	112TCA				
91	Benzene	BENZEN				

(Continued)

Unfiltered Modified Elutriate Analysis

for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	3
92	2-Chloroethylvinylether	CLETRE				
93	Bromoform	CHBR3				
94	1,1,2,2-Tetrachloroethane	TCLETA				
95	Tetrachloroethene	TCLETE				
96	Toluene	TOLUEN				
97	Chlorobenzene	CLBEN				
98	Ethylbenzene	ETBEN				
99	Acrolein	ACRO				
100	Acrylonitrile	ACRY				
101	N-Nitrosodimethylamine	ADMEAM	0.01		0.01	0.01
102	Bis(2-Chloroisopropyl)Ether	CLISOE	0.01		0.01	0.01
103	N-Nitroso-Di-N-Propylamine	NDRPAM	0.01		0.01	0.01
104	Nitrobenzene	NIBEN	0.01		0.01	0.01
105	Isophorone	ISOPHO	0.01		0.01	0.01
106	Bis(2-Chloroethoxy)Methane	CLETMA	0.01		0.01	0.01
107	2,6-Dinitrotoluene	26DNT	0.01		0.01	0.01
108	2,4-Dinitrotoluene	24DNT	0.01		0.01	0.01
109	1,2-Diphenylhydrazine	DPHHYD	0.01		0.01	0.01

(Continued)

Unfiltered Modified Elutriate Analysis

for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	3
110	Benzidine	BENZID	0.1		0.1	0.1
111	3,3'Dichlorobenzidine	DCLBEZ	0.1		0.1	0.1
112	Bis(2-Chloroethyl)Ether	BCLETE	0.01		0.01	0.01
113	1,3-Dichlorobenzene	MDCLBE	0.01		0.01	0.01
114	1,4-Dichlorobenzene	PDCLBE	0.01		0.01	0.01
115	1,2-Dichlorobenzene	ODCLBE	0.01		0.01	0.01
116	Hexachloroethane	HCLETA	0.01		0.01	0.01
117	1,3,4-Trichlorobenzene	TCLBEN	0.01		0.01	0.01
118	Naphthalene	NAPHTH	0.01		0.01	0.01
119	Hexachlorobutadiene	HCLBU	0.01		0.01	0.01
120	Hexachlorocyclopentadiene	HCLEPD	0.01		0.01	0.01
121	2-Chloronaphthalene	CLNAPH	0.01		0.01	0.01
122	Acenaphthlyene	ACENAY	0.01		0.01	0.01
123	Dimethyl Phthalate	DMEPHT	0.01		0.01	0.01
124	Acenaphthene	ACENAP	0.01		0.01	0.01
125	Fluorene	FLUORE	0.01		0.01	0.01
126	Diethyl Phthalate	DETPHT	0.01		0.01	0.01
127	4-Chlorophenyl Phenyl Ether	CPPETH	0.01		0.01	0.01

(Continued)

Unfiltered Modified Elutriate Analysis

for the New York/New Jersey Harbor Project

(Continued)

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	3
128	N-Nitrosodiphenyl Amine	NDIPAM	0.01		0.01	0.01
129	4-Bromophenyl Ether	BRPHPE	0.01		0.01	0.01
130	Hexachlorobenzene	HCLBEN	0.01		0.01	0.01
131	Phenanthrene	PHENAN	0.01		0.01	0.01
132	Anthracene	ANTRAC	0.01		0.01	0.01
133	Dibutylphthalate	BUPHTH	0.01		0.01	0.01
134	Fluoranthene	FANTHE	0.01		0.01	0.01
135	Pyrene	PYRENE	0.01		0.01	0.01
136	Butylbenzylphthalate	BUBPHY	0.01		0.01	0.01
137	Chrysene	CHRYSE	0.01		0.01	0.01
138	Benzo(a)Anthracene	BAANTH	0.01		0.01	0.01
139	Bis(2-Ethylhexyl)Phthalate	ETHEPH	0.01		0.022	0.01
140	Di-N-Octylphthalate	DIOPHT	0.01		0.01	0.01
141	Benzo(b)Fluoranthene	BEHFLU	0.01		0.01	0.01
142	Benzo(k)Fluoranthene	BEKFLU	0.01		0.01	0.01
143	Benzo(a)Pyrene	BEZPYR	0.01			
144	Indeno(1,2,3-c,d)Pyrene	INDPYR	0.01			
145	Dibenzo(a,h)Anthracene	BEAANT	0.01			

(Continued)

Unfiltered Modified Elutriate Analysis

for the New York/New Jersey Harbor Project

(Concluded)

Parameter Number	Parameter	Symbol	1 ppm	Duplicate ppm	2	3
146	Benzo(g,h,i)Perylene	BEPERY	0.01			
147	Sulfite	SO-3				
148	Sulfate	SO-4				
149	Chlorides	CL				
150	Total Organic Compound	TOC				
151	Total Inorganic Compound	TIC				
152	Total Carbon	TC				
153	Cyanide	CN				
154	Chemical Oxygen Demand	COD				
155	Biochemical Oxygen Demand	BOD				
156	Total Solids	TS	45,567.0		55,001.0	52,435.0
157	Total Suspended Solids	TSS	121.0		71.0	73.0
158	2,4-D	24-D	0.00001		0.00001	0.00001
159	2,4,5-TP	245-TP	0.00001		0.00001	0.00001
160	Methoxychlor	METOXC	0.00001		0.00001	0.00001

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